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THE
STATE OF THE ART
OF
WATER HARVESTING STRUCTURES

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FOREWORD

The problem of supplying drinking water in the villages are many and vary from region to region. In addition, there are a number of inherent constraints in the implementation of the water supply schemes. The geological variation in India is so much that the techniques of water targetting and supply also vary. In order to meet these challenges, National Drinking Water Mission mobilised application of science and technology inputs in an integrated manner and closely coordinated by State Public Health Engineering Departments to ensure cost-effective solutions of supply of adequate and acceptable quality of drinking water on a sustained basis.

One of the themes of the Mission is to lay emphasis on the water harvesting and conservation of water and recharge of aquifers. The experience of Mission has shown that the cost of water supply can definitely be reduced if the project is planned to emphasise in situ sources supported by community involvement and supplemented by rain water harvesting through improved traditional structures.

The water supply got severely affected due to repetitive drought in most part of the country causing disruption in rural water supply. Lowering of water-table and increase in brackishness created further problem. In this context the need of water harvesting structure is most important and cost-effective. The Mission tries to achieve this development of short and long-term measure in development and promotion of scientific methods and structure for arresting surface runoff, recharge of groundwater and collection and augmentation of such water for drinking purposes. This intervention was more required in arid, semi-arid and hard rock regions. Quite a large portion of rain water is lost through seepage and evaporation. In many hill regions including Cherrapunji there is a lot of rainfall but drinking water scarcity exists due to lack of ground water recharge, increased surface run off due to deforestation and lack of structure to arrest the run off.

Traditional water harvesting systems in the form of surface and sub-surface storage and roof catchment structures have been widely practised in many parts of the country. We are encouraging such structures in Mizoram, Meghalaya etc., North Eastern areas as well as in places like Orissa, Karnataka, Gujarat, Rajasthan etc., places. These systems have, however, been given little attention and priority in normal programmes. Some efforts have been made by various research organisations like CGWB, CAZRI, NGRI, SERC, etc. on development of techniques but their field application has to be intensified. Particularly the ferrocement structures propagated by SERC, Ghaziabad must be promoted extensively.

Recognising the need for integrating the water harvesting technologies as one of the important projects, the Department of Rural Development, Government of India, constituted a National Committee on Rain water harvesting in April, 1988 under the Chairmanship of Shri V.C. Pande, Secretary, Rural Development and its Working Group with Shri Mohd. Inamul Haq, Adviser (TM), as Chairman to workout the plan of action.

In order to crystallise the known and emerging knowledge on the subject from various cross section of people, it was felt desirable to visit areas, to pool the technical information, its feasibility, economic viability and social acceptability of water harvesting system in different geo-climatic region and to develop practical schemes and package for implementation in various States.

More than 40 papers have been received in this Seminar provides a forum for engineers, scientists, technologists, planners to present and exchange their views on the theme of seminar.

Other UN and bilateral agencies have also been invited to participate in this Seminar.

By the nature of multi-disciplinary resources and subject matter, it was felt desirable to divide the subject into following five broad technical sessions :

1. THE STATE OF ART OF WATER HARVESTING SYSTEMS.

2. SCOPE OF RESEARCH AND DEVELOPMENT - WATER HARVESTING STRUCTURES.

3. TECHNOLOGY INPUTS FOR WATER HARVESTING SYSTEMS ROLL OF REMOTE SENSING GSI-NGRI AND CGWB.

4. DESIGN - PACKAGES - SCOPE FOR IMPROVEMENT.

5. INTEGRATION OF WATER HARVESTING SYSTEMS INTO THE DRINKING WATER PROGRAMME - EVOLVING - GUIDELINES.

The co-ordinator of technical sessions have been requested to highlight all the papers relating to concerned session and to present an overall view of all the papers for discussion in each session to have an effective interaction.

At the end of the Seminar we expect to prepare a definite workplan for future.

I gratefully acknowledge the continuous encouragement and advises given by Sri V.C. Pande, Secretary Rural development. I am also grateful to Sri Mohd. Inamul Haq, Adviser (TM) for his contribution in building up the foundation of this seminar and preparing the State of Art and Design Packages. I thank the Chairman and members of the National Committee and Working Groups and toher associates for their expert guidance and preparation of guidelines. These deliberations have actually provided no beacon light to proceed to the path of success. I thank Govt. of Karnataka and particularly Sri Meenakshisundaram, Secretary, Rural Development and Sri Gulam Ahmed, Chief Engineer, PHED for their relentless effort to make the Seminar a success.

I congratulate the individuals and the groups who have contributed rich experience and knowledge seminar, and those who helped in collecting and compiling the seattered information available from various sources and documents and knitting these in the present form.

The voluntary agencies have a special talent to serve as promoters and catalysts. Their contribution in this seminar will enhance in experience of field level. UNICEF has been a very active partner in this programme. It's cooperation has been valuable.

We are also encouraged with the valuable messages received from Honourable President of India, Vice President of India; Prime Minister of India; Agriculture Minister, Govt. of India; Government of Karnataka and Chief Minister of Karnataka. Sri Poojary, Minister of State, Rural Development, Govt. of India spent his valuable time to inaugurate the Seminar. We are grateful to all of them.

In this effort there may be a large number of mistakes but hopefully in the greater intent of Science & Technology the participants will excuse them.

I am confident that the outcome of this seminar will translate into action projects for field application by those who are responsible for drinking water supply in villages.

Sd/-
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Mission Director
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Department of Rural Development
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NEW DELHI

14th December, 1988

INTRODUCTION

I. The programme of providing safe drinking water to all rural citizens by 1990 as per Decade requirement has been receiving a set-back in last few years due to frequent droughts in many parts of the country. The problem villages which were covered by providing drinking water sources are reported back as problem villages due to failure of sources, it has resulted in serious consideration to rain water collection in certain areas to facilitate storage of water and to improve and maintain ground water recharge so as to have assured water even during prolonged drought.

II. It has, therefore, been felt necessary to collect effectively the rain water at an appropriate season and to utilise it judiciously so that the requirement of drinking water is met with in a sustained manner for a reasonable period. For this purpose, Department of Rural Development has taken the initiative by pooling together the funds available under NREP, RLEGP etc. to encourage not only construction of new storage structures, but also for improvement of traditional structures. Instructions were issued to all the State Governments for taking effective steps for construction of Rain Water Harvesting Structures. In October 1987, about 32000 structures were provided. Large number of projects have been cleared under RLEGP programme for the purpose of construction of Rain Water Harvesting structures in various States.

III. It has to be agreed that Rain Water Harvesting systems have certain distinct advantages namely :

1. The rainfall water quality is excellent in most areas.
2. The concept is simple and easy to build.
3. The traditionally acceptable and local know how available.
4. The Operation and Maintenance of systems are easy.

Keeping these advantages in view the National Drinking Water Mission has taken a lead to get these systems documented, and suggest measures to improve these structures and also to make the PHED authorities to inbuild the concept of these structures in their day to day formulation of schemes as one of the alternatives to provide sustained water supply to rural areas.

IV. A National Committee is formulated on Rain Water Harvesting Structures under the Chairmanship of Secretary, Department of Rural Development on 4.4.1988. The Committee is made responsible to give advice for implementation of these schemes in hard core areas to bring abour proper co-ordination among various agencies/departments concerning with utilisation of ground water and surface water, to assist the National Committee a Working Group is constituted with Adviser (TM) as Chairman. The Working Group is asked to work out the modalities to achieve the objectives of the National Drinking Water Mission, to take conservation measures for sustained suply of water, to suggest improvement of traditional programme of Water harvesting systems to form an integral part of water supply. The Working Group is also entrusted with the job of preparation of state of the art on Water harvesting systems and to evolve guidelines for effective implementation of programme.

The Working Group met five times i.e. at Hyderabad, Pune, Ahmedabad, Shillong and Delhi and discussed with various organisations and could generate required data to fulfill the task assigned to it. Finally the work done by Working Group is placed before the National Committee.

V. The rain water harvesting structures which serve as collection of rain water, recharge of ground water and source of ecological balance etc. can easily be classified into three categories namely :

1. **Structures providing drinking water namely : NADI, TANKA, SANDFILLED RESERVOIRS, PONDS, ROOF TOP COLLECTIONS/HILL TOP COLLECTION, PLAT FORM, OORANIS (Tamil Nadu/Pondicherry).**

2. **Structures to facilitate ground water recharge namely : PERCOLATION TANK, KHADIN, ANICUT/CHECK-DAMS, SUB-SURFACE DAMS/ BARRIERS, INJECTION WELL.**

3. **Structures to arrest the scour etc. namely : GULLY PLUGGING, CONTOUR BUNDING.**

VI. Recognising that rain water collection has been a neglected area of study and improvement and in view of the renewed emphasis put on the utility and affordability of Rain Water Harvesting Structures, it is desirable that the Current Seminar will deliberate on it and will assist all concerned to help in providing sustainable water supply systems.

RAINWATER HARVESTING AND RECYCLING IN INDIA*

INTRODUCTION

Definition and scope :

Water harvesting is a new word coined for an ancient practice. Evanari *et al* (1971) furnish examples of water harvesting systems, thousands of years old in the Middle Eastern countries of Iraq, Israel and Saudi Arabia. The native Indian population of North America used water harvesting methods some 1000 years ago in ARizona (Morin and Matlock, 1975). The first definition of water harvesting, inthe modern context, comes from Geddes, as quoted by Meyers (1975) 'The collection and storage of farm waters either runoff or creek flow, for irrigation use'. Meyers (1975) also quotes Currier's definition : 'The process of collecting natural precipitation from prepared watersheds for beneficial use'. Meyers himself used the following definition : 'The practice of collecting water from an area treated to increase runoff from rainfall or snow melt. Pacey and Collis (1986) defined water harvesting as 'The gathering and storage of water running off surfaces on which rain has directly fallen' and not the 'harvesting' of valley flood water or stream flow. They limited the scope of water harvesting in their book to the collecting and conserving of rainwater at as early a stage as possible in the hydrological cycle to ensure the best use of rainfall, before it has run away into rivers and ground water.

From the above definitions it can be seen that water harvesting encompasses methods to induce, collect and store runoff from various sources and for various pruposes. Water harvesting techniques, in general, are characterised by the following :

1. They are applicable in general to arid and semi-arid regions where runoff has an intermittent character. Due to this ephemerality of flow, storage is an integral part of the water harvesting systems.

2. The methods depend upon local water such as surface runoff, creek flow and springs.

3. They are relatively small scale operations in terms of catchment area, volume of storage and capital investment.

Water harvesting in the context of rainfed (dryland) agriculture is in principle, the

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* *A contribution from Central Soil & Water Conservation Research & Training Institute Dehra Dun (ICAR), U.P. - 248195.*

maximisation of *in situ* rainwater use for increasing the productivity of the land. This may be effected either by inducing more water to soak into the soil profile or by storing the unabsorbed excess water in ponds and applying as supplemental irrigation at critical stages of crop growth.

WATER HARVESTING METHODS

Boers and Ban Asher (1979 and 1982), described the different water harvesting methods developed in desert regions. These include among others : Runoff Farming Water Harvesting (RFWH), Micro Catchment Water Harvesting (MCWH), Roaded Catchment Water Harvesting (RCWH) and Runoff inducement methods. Hollick (1982) reviewed the techniques for modifying catchments to increase runoff in the arid lands. Fujimra (1982) presents a collection of the papers presented at the International Conference of Rainwater cistern systems held at Honolulu, Hawaii during June, 1982 covering the different aspects of rainwater cisterns design across the semi arid and arid world. Pacey and Cullis (1986) in their book furnished material on the design, organization and overall implementation of 'appropriate' rainwater harvesting schemes for selected locations across the world. Verma (1983) reviewed the different methods of water harvesting practiced in the semi arid regions of the world and discussed their suitability in the Indian context.

WATER HARVESTING IN INDIA

The concept of water harvesting is not new to India. Water harvesting has been a traditional practice in the arid and semi arid zones. The Khadins in Rajasthan (Kolarkar et al 1983), Bandharas in Maharashtra, Bundhis in Madhya Pradesh and Uttar Pradesh and Tanks in Andhra Pradesh, Karnataka and Tamil Nadu and Adhars in Bihar are some of the examples of such traditional practices of water harvesting followed for centuries. Mukherji (1982) described the different water harvesting models followed traditionally in the arid and semi arid regions of India. There are about 5 lakh tanks in India catering to about 4.5 million hectares of irrigated area in addition to serving in most cases human and livestock drinking purposes. However some of these tanks have become unserviceable with their storage capacities reduced by as much as 50% due to rapid siltation incidental to catchment degradation. The introduction of large scale centralised water storage and supply systems through the storage reservoir - canal network systems have relegated these traditional practices into relative insignificance from public view.

Much of the innovative ideas developed and implemented by the farmers are not adequately documented and remain away from the public notice. An example of this is the intercepting and diverting of road-side culvert outflows for raising successful crops by some innovative farmers in the Hirakund catchment area in Orissa. Low earthen checks buttressed by loose boulder pitching down below the culvert outlet build up a temporary water cushion and depth which diverts the outflow, through a drop into a pick up channel and then into irrigated fields (Das, 1980). This technique is also followed in parts of Koraput District and the State Department is encouraging farmers to take up this practice in big way.

RESEARCH ON WATER HARVESTING IN INDIA

Though India has age old traditons of water harvesting as stated above, research efforts started in the country only during the 1950s and 60s at the Soil Conservation Research Demonstration and Training Centres operating under the administrative control of the then Central Soil Conservation Board of Govt. of India in the form of studies on water yields into dugout or impounding type of ponds from catchments under different land uses. The Central Arid Zone Research Institute at Jodhpur has done good work on methods of inducing runoff in desert catchments (Murthy *et al* 1980) and some of the hydrological aspects of water harvesting Murthy and Kalla (1980), Singh *et al* (1979), and Yadav *et al* (1979) have been studied. These efforts were followed up from the 1970s at the Research Centres of the then All India Coordinated Research Project on Dryland Agriculture, presently Central Research Institute for Dryland Agriculture, Hyderabad : Singh (1983), Venkateswarlu (1985) and Vijayalaxmi (1983) and at the Agriculture Universities. The ICRISAT has done substantial work on several aspects of water harvesting in both vertisols and alfisols of the region : Miranda *et al* (1983).

RESEARCH WORK DONE AT THE CENTRAL SOIL & WATER CONSERVATION, RESEARCH & TRAINING INSTITUTE, DEHRA DUN AND ITS REGIONAL CENTRES

Dhruva Narayana (1985) summed up the soil, climate, runoff and soil loss at different locations represented by the Institute and its centres. The research effort in water harvesting at the Institute and some of its centres has been mainly on the following lines :

1. Maximising in-situ utilisation of rain water by suitable land modifications.

2. Determination of annual water and sediment yields into the water harvesting facilities.

3. Harvesting and efficient storing of the readily unabsorbed rainwater, and

4. Identification of supplemental irrigation responsive crops and critical stages of crop growth where moisture stress affects the yields most.

DOON VALLEY (DEHRA DUN)

From long term water balance studies in a gauged embankment type of pond, Sastry *et al* (1981) reported 16.5% annual runoff. In case of freshly dugout ponds in Doon Valley Sastry *et al* (1981) reported high seepage rates of 10 cm/day. However when lined with brick mortar the rates reduced to 2 cm/day (Sastry *et al* 1982). With aging of the ponds, natural sealing due to sedimentation takes place and by about the 8th year, the seepage drops down to 4-5 cms/day in unlined ponds.

Singh *et al* (1981) reported about 85% increase in wheat yields over a base value of 19.31 q/ha due to one supplemental irrigation of 5 cms (rainwater harvested in farm ponds) either at presowing or at crown root initiation stage and recommended that the irrigation be given at presowing stage to avoid storage losses and command more area.

Bhushan (1978) observed increase to the tune of 205% in rice yields when the conservation bench terrace system of water harvesting is followed.

SHIWALIK REGION (CHANDIGARH)

Mishra *et al* (1980) through their pilot studies at Sukhomajri on operational basis opened up new vistas in water harvesting in Shiwaliks. It was a unique case of water sharing by entire village community comprising of both landed and landless persons. Such society participation provided for social fencing of the catchment ensuring for reduced sediment movement. They touched and influenced a whole gambit of the village life style. This has served as a model for large scale replication of the technology in the states of Haryana, Punjab and Himachal Pradesh.

Mittal (Personal communication) reports 26.3% runoff from an average seasonal rainfall of 623 mm. Sodium carbonate treatment on the bottom of a pond lined with brick masonry on sides, has resulted in the reduction of storage losses from 8 cm/day to 2.9 cm/day.

GUJARAT ALLUVIAL PLAIN REGION (VASAD)

Dhruva Narayana (1985) reported 41% to 52% runoff of the rainfall in the Vasad Region and Sharma *et al* (1981) report drought spells of considerable length during the crop growing season which indicates good scope of rainwater harvesting and recycling in the region. Nema and Chandra (Unpublished) as quoted by Singh (1983) report 20% to 50% increase in the yields of Bidi tobacco, safflower, mustard and chickpea. Nema and Kammanwar (1976) observe that 1.25 cm thick soil cement plaster (8:1) reduced the storage losses from the original 669 lit/m²/day to 232 lit/m²/day.

LOW RAINFALL BLACK SOIL REGION (BELLARY)

Located in the vertisols of the semiarid region of the Peninsular India with high potential for runoff formation, the region offers good scope for harvesting techniques.

Any attempt at making more water absorbed into the soil profile in the black soils has dramatically increased the crop yields. Rao and Rao (1981) reported that simple contour cultivation increased yields of *Rabi* jowar - 35%, Setaria - 22% and *Kharif* jowar - 66% while vertical mulching increased jowar grain - 50%. In another set of studies, Patnaik *et al* (1983) reported increased in the yield of sorghum crop by 27%, 45% and 120% due to contour cultivation, bund former bunds and organic trench ridging over the base yield of 12.3 q/ha in the up and down cultivated plot.

Hayavadan Rao and Chittaranjan (1971) reported 10% water yield from agricultural catchments in black soils. Chittaranjan and Patnaik (1980) and Patnaik *et al* (1984) report the failure of contour bunds in the vertisols due to the prolonged water stagnation upstream of the bunds due to which 15 to 20% of the gross area is lost for crop production. Patnaik et al (1987) introduced a new concept of conservation ditching which serves the dual purpose of a terrace and water harvesting at the individual field level. Conservation ditching is a comprehensive water harvesting facility with the whole gambit of harvesting, storing, lifting and utilisation of the rainwater being within the easy reach and resources of a small farmer of the scarcity tracts. Additionally it has the advantages of producing other useful biomass like fodder grasses, fuel and fibre plants.

Rama Mohan Rao *et al* (1977) identified the critical stages for moisture stress in different traditional dryland crops of the tract, such as, sorghum, cotton, safflower, sunflower and fox tail millet and quantified reduction in yields.

Hayavadan Rao and Chittaranjan (1971) and Patnaik *et al* (1982) reported low storage losses of 0.5 to 2 cm/day from different dugout farm ponds in the vertisols of the locality. The high clay content and montmorillonite clay mineral of the vertisols and the type of murrum present are considered the reasons for this low rate of seepage.

The centres at Agra, Kota and Ootacamund conducted studies over the years with their bearing on water harvesting such as annual water and sediment yields under different land uses, sealing of ponds etc.

In conclusion it can be summarised that the present status of research on water harvesting and recycling indicates that adequate information on storage losses and seepage control methods, lifting devices conveyance and application methods does not seem to be available. It is therefore essential to initiate research work on the following aspects in an integrated manner :

- Rainfall - catchment area - Runoff - Capacity of farm pond relationships.
- Quantification of seepage losses and the net water available.
- Efficacy of different sealing materials and economics.
- Lifting devices

  Efficient pond-to-field conveyance systems
- Command area development and application methods and remunerative crops and their critical stages.

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WATER HARVESTING STRUCTURES - OVERVIEW

1. The gross inflow of rain water is estimated at 178.5 M.ha.m of which utilisable flow is only 70 M.ha.m. Central Water Commission in 1977 estimated surface flow at 176.81 M.ha.m. of which utilisable surface water resources was 74 M.ha.m. The utilisable ground water resources based on replenishable mean annual recharge is estimated at 42.3 M.ha.m. The total utilisable water sources, both surface and underground are estimated to be 116.3116 M.ha.m of which about 77 M.ha.m may be utilised for irrigation and the remaining resources may be used for other requirements. The total water resources of India are almost same as those of United States of America, but the total area of the country is only 40% of USA and the population is almost 2-1/2 times. This will show the pressure on water resources available in the country.

2. Ancient desert dwellers harvested rain by redirecting the water running down hill slopes into fields or underground tanks. Modern farmers in arid lands have seldom harvested rain water in this direct way.

3. Water harvesting is relatively a new term and has been interpreted in different ways. Some consider that it includes water conservation and water augmentation. Actually, the term harvesting implies getting or capturing use of water (either surface or ground water) which was naturally not accruing to these systems and in that sense covers such diverse practices like cloud seeding, construction of dams, bunds etc. For arresting surface run off, aforestation, digging of ponds, construction of surface storage tanks and artificial recharge of ground water through water spreading, percolation tanks, recharge basins, injection wells etc. The term water harvesting should, thus, cover "Augmentation" but not conservation.

4. Though, rain falls, infrequently in arid lands, it comprises considerable amounts of water; 10 mm of rain equals 1,00,000 litres of water per hectare. Harvesting this rain water can provide water for regions where other sources are too distant or too costly, or where wells are impractical because of unfavourable geology or excessive drilling cost. Rain harvesting is particularly suited to supplying water for small villages, schools, house-holds, small gardens, livestock, wildlife etc.

5. since time immemorial, water harvesting systems in the form of surface and sub surface storage have been widely used. With the advent of piped water supply, the traditional water harvesting systems have been neglected and abandoned. Recently, due to consecutive droughts all surface water sources dried up and the yield from bore wells reduced considerably in most parts of the country. Besides, water table has lowered down and salinity has increased which have once again drawn the attention to the role of water harvesting structures in drinking water supply systems.

6. Rain fall harvesting is almost 4000 years old. It began in the Bronze Age, when desert dwellers smoothed hill-sides to increase rain water run off and built ditches to collect the water and conveyed to low lying fields. This permitted agricultural civilisation to develop in regions with an average rain fall of about 100 mm, an adequate rain fall for conventional modern agriculture. In modern times, but before 1950, only a few artificial catchments were built mainly by government agencies to collect water for livestock and wildlife on islands with high rain fall and porous soil like the Caribbean Island of Antigua. In Jaisalmer district of Rajasthan, water harvesting in Khadins for agriculture has been practiced for decades. In the 1950s interest in rain harvesting increased and some lower cost treatments were installed. One of the most extensive is in Western Australia, where several thousands of shaped compacted earth catchments supply water for both house-holds and livestock. Their performance is good when they are properly maintained. Approx. 240 ha of asphalt or asphaltic concrete catchment have also been constructed to furnish water for 32 small towns in Western Australia. In Western Rajasthan, rain water harvesting through roof top collection in house holds has been practiced since good olden times. Construction of Nadies for harvesting rain water in depressions through natural catchment for both human and livestock consumption are quite common in desert part of the country.

7. Before proceeding with the designs and specifications of water harvesting structures, the basic parameter required is the water demand. As per the present guidelines from Government of India under 'Minimum Need Programme' and 'Accelerated Rural Water Supply Programme', 40 LPCD water requirement is catered through water supply systems in the rural areas except in the western desert part where livestock population is high. In this desert part of the country, the water supply systems provide 70 LPCD water based on human population, but designed to cater water requirement of cattle also. Out of the above requirement of water, the water required for drinking and cooking is estimated to be 10 LPCD. It is felt that the water harvesting structures, if provided to cater for the total demand of water will become prohibitively expensive. Water harvesting structures may be considered to be used in conjunction with normal water supply systems as a supplementary source and not as a replacement. Another important consideration while designing the capacity of water harvesting structure is the evaporation and seepage losses in the area. Studies have been carried out about the evaporation losses in different parts of the country and due provision will have to be made while estimating the capacity of the water harvesting structure for the likely evaporation losses in the area. As regards, seepage losses, various lining systems are available like lining with clay and murrum, tile lining, polythelene film lining etc. The third most important consideration while arriving at the capacity of the storage is the period for which water is required to be stored. While in some parts of the country where rain fall occurs around 9 months in a year, storage required may be only for 60-90 days but in the areas where rain fall occurs for 30-60 days only during a year, storage may be required for 11 months in a year.

8. Different practices are prevalent in different parts of the country for water harvesting and some practices are prevalent in other countries which have not been tried here. The water harvesting structures may be classified in the following manner :

(1) FOR DRINKING WATER SUPPLY

(a) **Nadi :**

(i) Water harvesting from natural surface for surface storage structures.

(ii) Augmentation of surface water from treated catchments.

(iii) Evaporation control measures.

(iv) Seepage control measures

(b) **Tanka.**

(c) **Roof water harvesting.**

(d) **Sanitary Diggies.**

(2) FOR CONJUNCTIVE WATER USE

(a) **Khadin.**

(b) **Percolation tank.**

(c) **Anicuts/check dams.**

(d) **Gully plugging.**

(e) **Sub surface barriers for artificial recharge of ground water**

(f) **Abandoned quarries for water harvesting development.**

(g) **Contour Bunds.**

(3) OTHER POTENTIAL WATER HARVESTING SYSTEMS

(a) **Sand filled reservoir.**

(b) **Flat batter tank.**

(c) **Roaded catchments for maximum run off.**

9. Details about each of the structures referred above follows.

TANKA

HISTORY

'Tanka' is a local name to a covered underground tank, generally constructed of masonry or concrete for collection and storage of surface runoff. The development of such structure, can be one of the answers to the problems of Perennial drinking water scarcity in the villages of western Rajasthan.

The provision of tanka near religious centres, Schools and in the individual house hold has been the practice since old times. For household use, the tankas are usually small and fed by rainwater from house tops. The history of Marwar reveals that the first known construction of tanka in this region was during the year 1607 A.D. by Raja Sursinghji in village Vadi Ka Melan. Further in the Mehrangarh fort at Jodhpur, a tanka was constructed during the regime of Maharaja Udaisinghji in year 1759 A.D. However, during the great famine of 1895-96, the construction of tankas was taken up on the wider scale in this region. In the recent past, the development of such structures have also been reported from other developing countries such as Botswana, Ghana, Kenya, Yemen, Sri Lanka, Thailand and Indonesia naming as tanks or cisterns.

TRADITIONAL METHODS

Practically every dhani now has one or more tanka for rainwater harvesting mainly for drinking purposes. According to the economic conditions, people of this area have devised their own methods for constructing these structures. Looking to the present status, it is obvious that the tanka system does not ensure an adequate supply of water throughout the year; this is mainly due to the meagre rainfall and inadequate catchment areas left for harnessing the funoff. Moreover the catchment areas prepared are not proper regarding the generating of runoff. Due to all these factors including the type of constructions, tankas fail to meet the annual requirement of drinking water. In the constructional aspects, tankas on individual dhani basis are circular in shape having almost similar depth to diameter, varying from 3.00 to 4.25 m. Since stones or bricks as building materials are not available at all places in duny areas and as these are relatively costly, after excavation in proper circular shape, lime mortar is used to plaster the bare horizontal and vertical soil surfaces to a thickness of about 6 mm. A second layer of plaster of cement mortar is applied to a thickness of about 3 mm. The top is covered with *Zizyphus numularia* thorns. With simple lime plastering on the bare soil surfaces, the useful life of a tanka becomes limited to a maximum extent of 3 years.

The catchments of tanka are made in variety of ways using locally available sealing materials. The generally used materials are pond silt, murrum, wood coal ash, gravel etc. After clearing the soil surface of vegetation, land is given a smooth slope of 3 to 4 percent towards the tanka, pond silt is spread in a 3-4 cm thick layer. During the rainy season, after the first shower, this layer is compacted and made Semi impervious by a local compaction technique consists of rolling of *crotalaria burhia* and sand. In places where tank silt is not available, a layer of 5-7 cm. of murrum is spread over the catchment. At the onset of monsoon, sheep and goats are made to move over the murrum again and again till the surface is compacted and becomes impermeable. During this process, water is also sprinkled, if needed. Normally wood coal ash is not used as sole surface sealing material, yet it is used to repair the catchments made up of pond silt and murrum locally. The ash settles, fills the pores and makes the surface water proof.

STRUCTURAL COMPONENTS OF IMPROVED TANKA

i) Catchment

It should be impermeable and smooth to obtain improved hydraulic efficiency.

ii) Silt Collecting Gutter

It is provided to arrest the sediment load before the inlet points.

iii) Side wall & Base slab

These are main structural components, provided to control seepage losses and also to prevent earth caving from sides. Stable material shall be used for construction.

iv) Catch pit

This is made in the form of a depression in the base slab to facilitate drawing complete water from the tanka.

v) Top Cover

It is required to control evaporation losses and to prevent pollution of water stored by foreign materials. An opening in the cover shall be provided for withdrawal of water.

(2) STRUCTURAL COMPONENTS OF IMPROVED DESIGN OF NADI

i) Catchment of Area

Location and size of a Nadi depend on the Catchment Area it commands. It should be located in areas with lowest elevation to have the benefit of natural drainage and minimum excavation of earth. Soil construction in the catchment area should preferably be impermeable. If necessary, the catchment area may be prepared artifically by soil conditioning wherever possible.

ii) Silt Trap

Silt Trap is provided at the inlet point to prevent sediment load enter into the Nadi. The size of the Silt Trap shall be designed keeping in view the site condition, duration and intensity of rain fall. Silt Trap should be cleared regularly.

iii) Inlet

A suitable size of inlet is provided for allowing water into Nadi. The inlet should be stone pitched to prevent soil erosion. A mesh should be provided at inlet to prevent floating materials enter into the Nadi.

iv) Side Walls & Beds

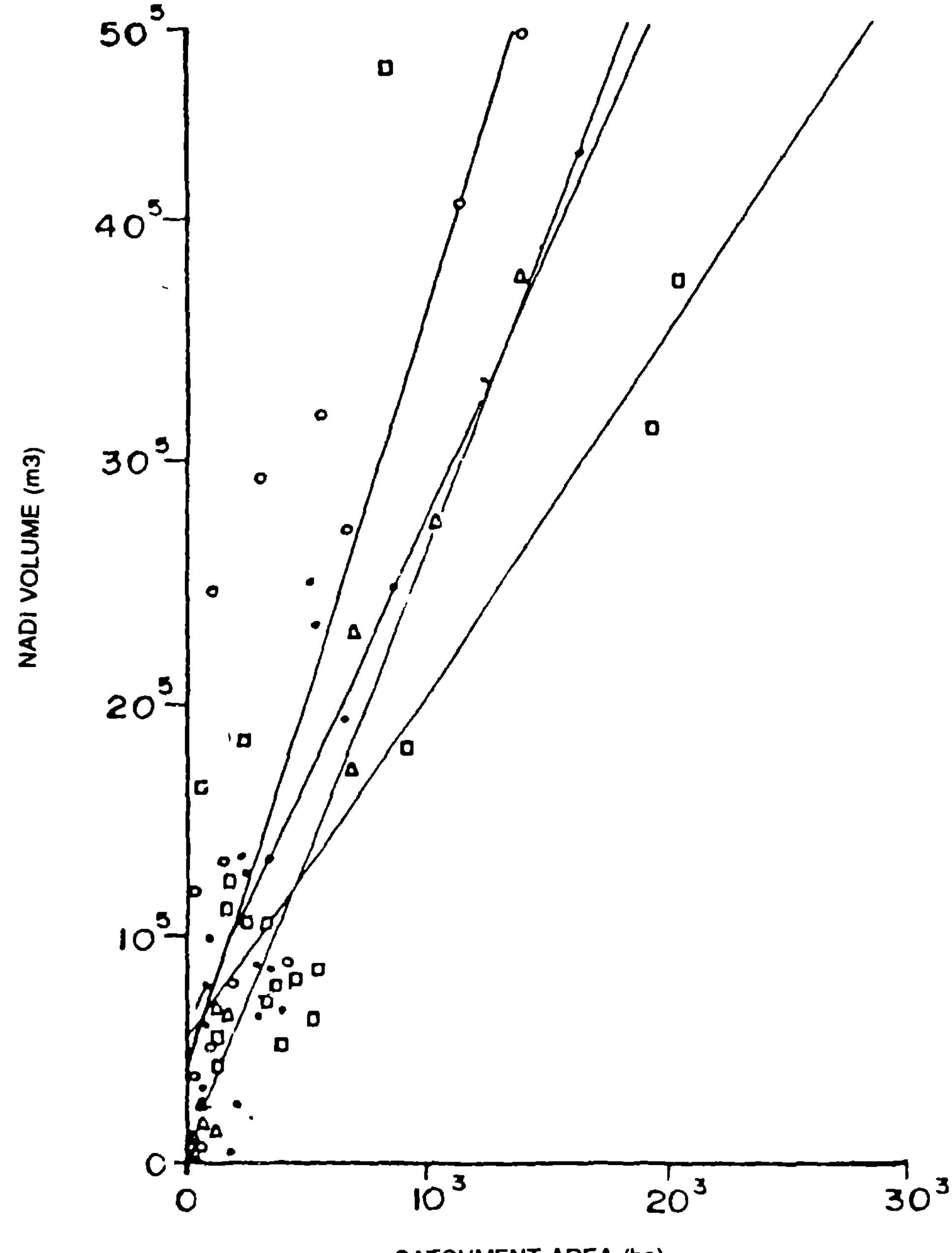
These are the major structural components of Nadi. The slope of sides shall depend on the soil condition. In order to prevent seepage losses through sides and bottoms, these are lined with LDPE Sheeting or stone-pitchning. LDPE Sheeting should be embedded properly.

v) Outlet

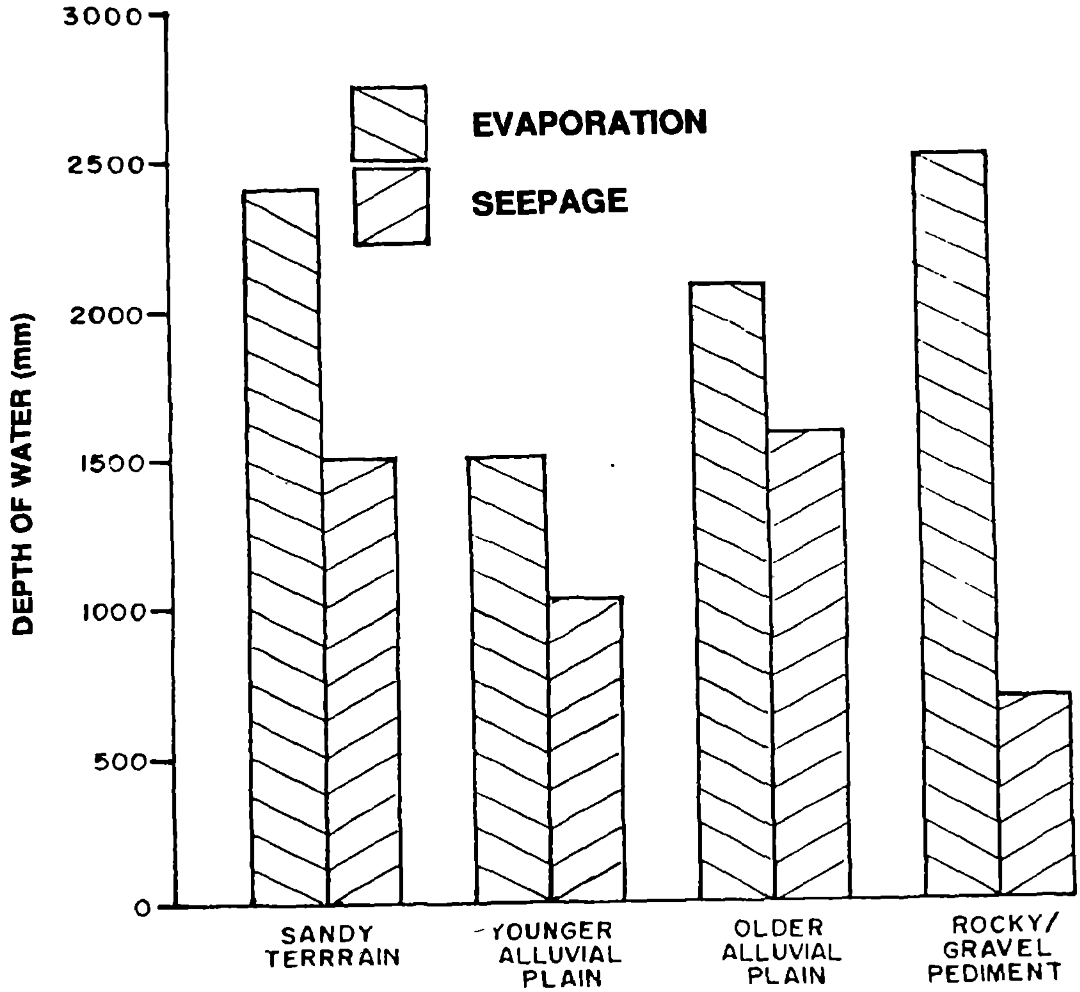
An outlet is provided to allow excess water to spill over. The outlet should be stone-pitched to prevent soil erosion.

vi) Exploitation Wells

An exploitation well is constructed at a suitable point of Nadi to facilitate withdrawal of water. The well is constructed by raising two masonary wing walls and one front wall as shown in the drawing. A suitable platform shall be constructed, fitted and fixed with iron fixures for Pulley and Hand Pumps.



NADI VOLUME IN RELATION TO CATCHMENT AREA IN SANDY PLAIN (o), DUNE COMPLEX (Δ) YOUNGER ALLUVIAL PLAIN (□) & ROCKY/GRAVEL PEDMENTS (•)



ANNUAL EVAPORATIVE AND SEEPAGE LOSSES FROM NADIS

vii) **Withdrawal Arrangement**

Withdrawal arrangement is done through pulley and bucket system or by hand pumps. The later is preferred. To avoid manual withdrawal, installation of wind mills can be thought wherever feasible.

viii) **Animal Trough**

This is provided at least 30m away from the withdrawal point. The trough should be connected with Channel/pit for flow of water to the trough to meet the drinking water requirement for cattle and live stocks.

ix) **Fencing**

A barbed wire fencing should be provided around the Nadi to avoid unwanted human and animal entry into Nadi to prevent pollution.

KHADIN

HISTORY

Water harvesting and runoff farming has been an ancient practice in various parts of arid zone of India. 'Khadin' is one such system basically innovated for runoff farming by the Paliwal Brahmin Community in Jaisalmer area in former Jaisalmer State, in 15th Century. It has quite a similarity with method practiced by people of Ur in trag 4500 B.C., or later by Nabateans in the middle east. Similar system is also reported to have been practiced 4000 years ago in Negev desert, as also till 500 years back in USA by ancient people in south western Colorado, particularly at site now known as Mesa Varde National Park.

In arid Rajasthan, though it was started in 15th century, the idea slowly spread over other parts too. In Jaisalmer, the ruler used to encourage people to develop this system on suitable sites, grow and develop agriculture and share the part of it with ruler, who would remain the owner of it. However, later Paliwal community was either driven out or left the Region and for long period, no new Khadins could be made but old Khadins continued to be used. However, their proper management got neglected. Still, there are as many as 500 big and small khadins in present Jaisalmer district which are still productive with even 40 mm rainfall.

STRUCTURAL COMPONENTS OF KHADIN

i) Catchment

Rocky hills terrain around a valley including the valley constitute the catchment area of a Khadin. Stony gravels, wasteland with gentle slope in the form of a valley can also form the catchment area of such structure.

ii) Earthen Embankment/Bund

At the lower point of the valley earthen bund is constructed to arrest the run-off. The stored water helps crop utilisation as well as recharging of ground aquifer.

iii) Spillway

Spillway of stone masonry is provided in the Bund to let excess water to pass over.

iv) **Sluice**

A sluice is provided at bed level to drain out standing water, if any, in Khadin at the time of bed cultivation.

v) **Khadin Bed**

On the upstream of the Bund, the area where water spread over constitute the Khadin Bed. This area is used for crop cultivation on the stored soil-profile moisture.

SAND-FILLED RESERVOIRS

HISTORY

In many arid and semi arid lands harvesting and storing rainwater in surface reservoir or village tanks being practiced over centuries is still the major source of water supplies in remote areas for human and livestock consumption. A large share of this precious water get lost through evaporation from free water surface of tanks leaving people to struggle for water during lean period.

Sand-filled reservoir system of water harvesting is being practiced for storing water in pores between the particles of material below ground surface level to shield it from the evaporation. In arid environments such as Indian desert, where rainfall is scanty, annual average evaporation far exceed the annual average rainfall, and most of the rivers are ephemeral with abandoned sand and gravel, sand filled reservoir may be an additioal source of water supply.

Sand filled reservoir system of water harvesting is an old practice in many African and South American countries. In South West Africa, this system has been developed on a large scale for fresh water supply in sustained manner for a reasonable period.

Water use from river bed was first initiated in 1849 in South West Africa but first sand filled dam was constructed in 1886. In Namib desert, sand filled dams have been used since 1907 for supplying drinking water to livestock. Sand filled water storage tanks developed in Sudan are in use for rainwater harvesting from an early time. Recently plastic lined rock-filled tanks were built in Arizona, U.S.A. for evaporation control. In India, this technology is yet to be tested.

STRUCTURAL COMPONENTS OF SAND/ROCK FILLED RESERVOIR

A. Salient Features of Sand/Rock Filled Tank

i) Catchment

Catchment area for Sand/Rock filled reservoir should be hilly terrain with natural designed drainage towards the pond.

ii) **Tank/Pond**

Tank should be constructed at lower elevation to facilitate natural drainage. The size of the tank will depend upon the rainfall pattern, catchment characteristics and water demand. The Tank should be provided with Silt Trap inlet and outlet arrangement. The sides and bed of the Tank should be properly lined with water proofing materials to prevent seepage losses.

iii) **Filling Materials**

The Tank is filled with Course Sand or loose rock with adequate voids. The voids form the storage of rain water in the pond. The advantage of such storage is that there will be minimum losses due to evaporation. The water will be of good quality due to natural filtration and chances of contamination is remote.

iv) **Withdrawal Arrangement**

Water supply from the tank is maintained by installing shallow tubewell or handpump or by constructing small diameter exploitation well in the tank with manual withdrawal arrangement.

v) **Fencing**

A barbed wire fencing around the tank is provided to restrict the unwanted human and animal entry in the tank.

B. Sand-filled Dam

A stone masonary dam across perennial river/stream in hilly terrain is constructed and river bed is filled with sand and gravel deposits carried by floods during monsoon period. This bed forms the storage reservoir. Initially dam height is kept few centimeter above the bed and it is raised in stages.

FLAT BATTER TANKS

HISTORY

Flat batter tank system of water harvesting is relatively new technique, developed in mid sixtees by farmers and contractors in the Esperance district, Australia. The technique has similarities with the "dew pond system" in East Yokshene, England, and have since been rendered obsolete by reticulation.

Flat-batter tanks are yet to be started in this country.

STRUCTURAL COMPONENTS OF FLAT BATTER TANK

i) **Batter/Catchment**

Batter/Catchment is the integral part of tank. It is formed out of the excavated material from the tank spread out evenly with a gentle slope of 1%.

ii) **Tank**

Tank is constructed in the centre and filled with run off water received from the batter. At the outer periphery, a small bund is constructed to prevent entry of water from all side. Water is guided into the tank through gutter and a pipe inlet at a suitable point.

iii) **Withdrawal Arrangement**

Water supply from the tank is made by constructing a small exploitation well with proper arrangement of hand pump pulley system.

WATER HARVESTING FROM ROOF TOB, PLATFORMS AND HILLISLOPES

The collection of rainwater for drinking water supply involves not only the collection of rainwater but also its safe storage in a closed reservoir/tank. Water is tapped from this reservoir for use.

A rainwater harvesting system (RHS) consists of the provision of the following components :

1. **Catchment area i.e. water collection surface**

    (i) Roof (Fig. 4)

    (ii) Watershed management (Fig. 5)

    (iii)Hill slopes (Fig. 6)

    (iv)Platforms (Fig. 7)

2. **Inflow Structures**

    (i) Gutter - For collection of rainwater

    (ii) Inflow Pipe - For transfer of rainwater to reservoir

    (iii)Filter - For filteration of water to remove suspended impurities

3. **Storage tanks - For storage of water during periods of insufficient or no rainfall**

    (i) Above ground

    (ii) Under ground

    (iii)Partly underground

4. **Out Flow structures**

    (i) Tap for the over ground tanks

    (ii) Hand pump or bucket pulley system for underground tanks

1. CATCHMENT AREAS

It is important to consider catchment surfaces in more details because it is the nature of the catchment which most clearly distinguishes rainwater collection from other kind of water harvesting. Specifically, catchments, used to collect rainwater, are frequently artificial surfaces or else are ground surfaces which have been specially prepared and demarcated. The catchments should be made of such materials which will not add contamination to water. For potable water, the catchment area may be one of the following :

(i) **Roof** (Fig. 4).

Rainwater may be collected from any kind of roof. The roof may be composed of :

(a) Corrugated galvanised iron sheet or aluminium sheet
(b) Ferrocement roof
(c) Thatched roof, covered fully with PVC sheet or non erodable mud plaster
(d) Roof with tiled top or cement concrete surface
(e) Wooden roofs with PVC sheet covering (temporary structures) or even tent roofs

Tiles, RCC, Ferrocement or metal roofs are easiest to use and may give the cleanest water. The thatch roofs made of grass thatch, palm leaves are also feasible. The only common roof unsuitable to collect water for drinking, is a roof with lead flushing or painted with a lead based paint. It is suggested that roofs made of asbestos sheeting should not be used if fibres are getting detached from its damaged surface areas. Such a roof may be covered with plastic sheet for avoiding contamination of water by Asbestos fibres.

In view of the relatively small individual roofing areas, the construction of roof is recommended to be in single slope for obtaining considerable savings in cost of gutter and ridge. The slope should be directed towards the enterance of the house so that the storage tank can be placed at the front of the house. No trees or other obstacles should overhang the roof so that entire roof area, to be utilised, could be exposed to the rain.

Many agencies have advocated not to use thatch roofs, which may cause contamination of water. Water from a well thatched roof does not present significant hazards to consumers. Greater precautions may be advisable to ensure that debris from the roof does not enter the tanks. For ensuring this, all the damaged thatch areas may be periodically repaired. The most important consideration however, is that if a scheme is to help the low-income groups in villages, there may not be any choice but to tackle the problems of collecting water from thatch or palm-leaf roofs, either by using a low level water collection tank by devising means of attaching gutters and open tanks below them Fig. 7.

In West Africa, rain water has long been collected from thatched roof and there appears to be no strong objection on grounds of taste to its use for drinking. In some places, with thatch of other types, water from thatched roof is often coloured and although it may be fit for drinking, people may dislike it due to colour.

As a precautionary measure, thatched roofs may be covered with plastic sheets. A thin bamboo strip frame may be fixed over it for keeping the sheet in positin. Nylon thread/ cord may be used for tying such frames. The sheet is rolled down at the roof edges. Covering of roof will prevent effect of bad smell and mixing of straw debris in water and will make it acceptable by consumer.

In case, a new roof is to be constructed as part of the scheme, it may be preferably of G.I. sheets, ferrocement or of any other material which will avoid contamination of water. One advantage in collection of rain water from house roof is that the roof is already available and so additional investments are limited to the expenditure on gutters and tanks only.

ii) Platforms

Platforms, for rainwater harvesting, may be either

(a) Raised platforms or
(b) Barricated ground surfaces

(a) Rain water harvesting from raised platforms

Platforms or high level earth deposits, sloping to one side provide a good surface for collection of the rain water (Fig. 7). Following precautions are to be followed for getting potable water :

— Catchment area is kept free from the approach of animals.

— Faecal contact is avoided. For this, the area is prohibited for easing of human beings which is common practice in the villages.

— Platforms are cleaned and maintained properly by the owners.

— Inlet levels of storage tanks installed for these systems, are kept sufficiently above the ground level so that surface runoff does not enter the tank directly without passing through the filter.

Platforms are provided with some lining or top surface covering for preventing turbidity in the water collected. Plastic sheet lining with bamboo strip frame for keeping it in position, soil cement lining, brick tile lining, covering with a layer of grit or coarse sand or covering with bamboo mats are some of the methods which could be adopted depending upon the situation and availability. Plastic sheet covering with a bamboo or any other local wood strips of tree branches is preferred due to easy carry out method. Normal plastic sheet may serve only for two to three years if left exposed to sun specially during summer. Soil cement lining will be suitable as it may work for very long periods and will not have any maintenance problem though its initial cost may be higher than Plastic sheet lining.

(b) **Rain Water harvesting from ground surfaces :**

The collection of rain water from ground-level catchments is sometimes possible using a hard surface created for some other purposes like school playgrounds, meeting ground, tennis courts etc. Thrashing floors have been successfully used in Botswana and other places. UNEP has proposed a classification of treatments for surface ground catchments which, with one addition, is as given below:

— clearing sloping surfaces for removing vegetation and loose material;

— improving vegetation management by planting with different species or by cropping;

— mechanical treatment of soil, including smoothing and compacting the surface, as on contour strips and microcatchments;

— making a hard surface using traditional soil stabilization techniques suitable and safe;

— reducing soil permeability by application of chemical such as sodium salts;

— applying chemical binders such as asphalt to seal the surface;

— covering the catchment with conventional paving materials;

— covering the catchment with other rigid materials;

— covering the catchemnt with flexible/plastic material;

The catchment area used for collection of rain water for drinking should be fenced properly for preventing entry of men and animals. This is necessary for keeping the area free from contamination. Most of these techniques fall into one or other of two main groups firstly those which involve treatment of the soil itself, either mechanically or with chemicals, to reduce infiltration by rain water and achieve greater runoff, and secondly, those which entail covering the soil with another material, as with the last three items in the list.

iii) **Hill slopes**

Hill slopes are used as catchment areas for the collection of rain water. The rain water flowing down the slopes is collected by constructing cross drains to divert the flow of water. This diverted water is taken to the under ground or above ground storage tanks or reservoirs through pipeline or covered masonary drains (Fig. 6). To stop the contamination, silt traps are used in these schemes. The collected water may carry certain impurities from slopes of the hills, so necessary purification of water may be needed. Raw water is generally used for live stock and irrigation purposes.

iv) **Rain water harvesting through water shed management**

Where the volume of available rainwater runoff is very large, small check dams are often constructed for acting as barriers for stopping and diverting water flow to underground large capacity tanks (Fig. 5). Generally water collected in such a manner is used for livestock and irrigation but it can also be used for domestic purposes after filtration and chlorination. The main danger in using such ground water for drinking are faecal and pesticide contamination from catchment areas. If the check dam system can be constructed in such a manner that first rainwater is permitted to flow out of the area and subsequent water is collected, then this danger can be minimised. Presently, these check dams are constructed in earth, or in brick or stone masonary.

SERC, Ghaziabad has developed a system of precasting and assembling of ferrocement check dams for diverting water in watershed management schemes. Centre has developed units for clear heights upto 150 cm and these have been tested at the laboratory and found to be leakproof and easy to produce and assemble. A system of bye-passing first wash off floods is being implemented in this system. Fig. 9 presents the details of this system.

ANICUT

HISTORY

The anicut is a structure which intercept the water from local catchment and store it for optimum utilisation. Such structures not only reduce the erosive velocity of runoff but also prevent the gullies from further enlargement. The retained water behind the structure can be used for lift irrigation and as drinking water for the human, cattle and wild animals. The anicuts recharge the downstream wells and the submergence area can be used for cultivation during the dry season. In a case study, the groundwater recharge was enhanced upto 35% during a period of three years by the construction of an anicut on an ephemeral stream near Jodhpur, Rajasthan.

In Gujarat, on the Saurashtra coast, the anicuts not only recharge the sweet water into the surrounding area but also prevent the saline ingress towards the fertile and the valuable coastal areas.

PREVALENCE

The anicuts, check dams, Nala bunding and Bhandaras are similar structures and have been widely adopted in Southeast Rajasthan, Gujarat, Maharashtra, Madhya Pradesh and in hard rock areas of deccan plateau. These structures have been in Vogue since the old days and are very popular.

STRUCTURAL COMPONENTS OF ANICUT

i) **Location & Catchment**

Anicut is constructed across nallah, gullies, rivers etc. to interrupt flow of run-off from the Catchment area. Catchment is usually hilly, undulating terrain with ephemeral streams.

ii) **Bund**

Earthern bund is made across the Stream to intercept flow of water from the Catchment. The stored water can be utilised for irrigation and drinking purposes. It also helps in recharge of ground water in the vicinity. The Submergence area is used for cultivation. The size of the bund depends upon catchment characteristics, rainfall runoff pattern, etc.

iii) **Spillway**

Masonary Spillway is provided in the bund to let excess water to overflow.

GULLY PLUGGING

HISTORY

Gullies are a symptom of a functional disorder of the land, improper land use, and are the most spectacular type of soil erosion. As per the recent estimate, 4 m ha are affected by such problems in about 12 states, while another 4 to 6 m ha of table land, including some of the command areas, are threatened. However, with proper management, the runoff through gullies can be harvested for groundwater recharge and for human and livestock drinking. In western countries, the gully plugging works started as long as the year 1900. However, in India such works were taken up on extensive scale since 1960 in Gujarat, Maharashtra, Madhya Pradesh and Rajasthan.

Gullies and ravines (a system of gullies) are found along the rivers of Chambal, Yamuna, Mahi, Sabarmati, etc. and are mainly located in Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat. Gullies are also seen in the plateau region of Eastern India along the foothills of Himalays and in Deccan plateau. All these areas require gully control and water conservation measures in the form of gully plugs, check dams and drop structures. Such work has already been taken up on a larger scale in these areas.

STRUCTURAL COMPONENTS OF GULLY PLUGGING

i) **Location**

Gullies are plugged at intervals with a view to reduce the velocity of flow. This will also help, control further erosion in the gullies and in the catchment areas. Such structures also help recharge of Ground water.

ii) **Plugging Materials**

This can be of brick masonary, earthern bund, sand bag, brushwood or any other suitable local material.

PERCOLATION TANK

HISTORY

Technological developments in the pumping method and well construction have resulted in large scale exploitation of groundwater. In many countries, which have to face the vagaries of monsoon, dependability of groundwater have increased tremendously. In arid or semiarid regions, availability of surface water is either lacking or is inadequate and storage of surface water is also uneconomical on account of high evaporation losses. Proper storage and management of available groundwater resources therefore, is very essential. The replenishment of groundwater reservoirs in the arid and the semi-arid regions is necessary because the intensity of normal rainfall is grossly inadequate to produce any moisture surplus under normal infiltration conditions. Although artificial groundwater recharge methods have been familiar in the developed nations over the past several decades, their importance was felt in the developing nations like India, only during past two or three decades. Methods like nala bunding, percolation tanks, trenching along the hill slopes and around the hills, etc., are being practiced in many parts of the country, but advantage of such projects could not be obtained for the want of scientific orientation of the programmes. A thorough and detailed knowledge of the geological, hydrological and morphological features of the area is necessary for selecting the sites for such recharge structures.

Percolation tanks are constructed for impounding surface runoff to create small storage and for induced recharge to groundwater through percolation. Construction of this structure takes into account the catchment area, likely runoff, design storage at the site as well as the area of benefit from the structure. The construction of such structure is considered to be very useful as means of water conservation and to strengthen the drinking water and irrigation water sources.

STRUCTURAL COMPONENT OF PERCOLATION TANK

Location & Catchment

Percolation tanks are generally constructed on the small stream or rivulets with adequate catchment. Rocky hilly terrain with defined drainage system are suitable catchment for this type of structure. The catchment area should be sufficient to fill in the tank in the normal year of rainfall.

SUB-SURFACE BARRIERS FOR ARTIFICIAL RECHARGE

HISTORY

In many of the dry regions in the world, an adequate supply of water for irrigation as well as for drinking during dry seasons constitutes a problem of paramount importance. Such supplies will depend on the storage in the form of surface reservoir or groundwater. The availability of groundwater invariably sustained on the recharge from various sources. Recharge of groundwater may take place direct from rainfall or from aquifer with intake outside the area or from sandy floors of ephemeral drainage channels. The second case is rare under arid climatic conditions. Recharge from direct rainfall is relatively less important in arid region because of high evaporation losses. The most estimates place it below 5 percentáge of rainfall. Moreover in sandy plains, this recharged water seldom reaches the water table and likely it may be limited to the years of exceptionally high rainfall.

The creation of surface storage reservoirs is often restricted by lack of suitable storage sites. Moreover the runoff drained by streams in these reservoirs is heavily loaded with suspended sediments which ultimately reduce the useful life period of the reservoir. Also the stored water is subjected to the high rate of evaporation.

The rivers flowing ephemerally often have wide beds and low banks. These wide beds, constituting the upper boundary of the previous deposits, form an excellent surface for infiltration during river surface flow. It has been reported that the infiltrated water will penetrate the under lying rocks through suitable fissures, the outstanding example being in limestone areas. Recharge into alluvial fill is practical important in piedmount zones where it is favoured by the greater frequency and volume of flow and by coarseness of alluvium.

Recharge in desert areas, whether direct from rainfall or through stream flow always naturally be irregular and discontinuous reflecting the variable nature of rainfall and runoff. Wells located along the banks of streams show immediate response of recharge during the runoff in the streams but ceases during dry period with insufficient replenishment of the aquifer. The meagre recharge during runoff period does not sustain a sufficiently long period due to which scarcity of water is felt. To some extent the yield of the such wells could be improved by abstracting the sub-surface flow of Sandy bed streams, by sub-surface semi-permeable barriers.

STRUCTURAL COMPONENT OF SUB-SURFACE BARRIERS

i) **Location**

Sub-surface barriers are constructed across perennial rivers and streams for abstracting the sub-surface flow of sandy bed stream.

ii) **Structure**

This is constructed with angular rock pieces arranged in the form of dry masonary wall of 1 m width and 5-7 m high and placed 1.5 m below the sand surface in the river bed, depending upon the site. Bottom of the structure should rest on impermeable hard rocks not far below the river bed. The system helps in recharging ground water and can be exploited by digging shallow wells in river bed for human and livestock consumption.

iii) **Tank**

Percolation tanks are constructed for impounding surface runoff to create small reservoir. Water is allowed to percolate down for re-charging the ground water. The surface area to volume ratio of tank is kept minimum to reduce evaporation, losses. Removal of Silt from the tank bed before the onset of monsoon is done to enhance recharge.

CONTOUR BUNDS

HISTORY

Contour bunding is one of the Soil and Water Conservation measures, carried out for watershed management programme. The term contour bunding used in India is same as 'level terraces' and 'ridge type terraces'. Contour bunds act as a barrier to the flow of water and at the same time impound water to build up soil moisture storage. Selection of site for bunding should be done judiciously. For an example, contour bunding in deep black soils failed due to wide spread breaches and water stagnation for longer period due to poor infiltration etc. In such soils, it was recorded, the yield of every crop in contour bunded areas were lower than the unbunded areas. On the other hand, contour bunding done in areas having rainfall less than 60 cm and permeable soils, assisted in intercepting the overland flow and made it to infilter into the soil.

Two types of contour bunds - narrow based and broad based, are constructed. Narrow based bunding in agriculture lands is normally not preferred due to considerable hinderance in farming and transportation of equipment from one terraced field to another. Moreover the narrow based bunding waste more than 6% of area from cultivation.. Broad based bunding does not interfere with the movement of equipment and no area of the field is lost from cropping. Broad based bunds are therefore preferred in agricultural lands.

STRUCTURAL COMPONENTS OF CONTOUR BUNDING

i) **Location**

This system is being practised for conserving moisture in soil profile for cultivation. This is located at fixed contour intervals.

ii) **Bund**

A series of earthern bunds are constructed at fixed contour intervals to intercept flow of water to build up soil moisture storage. Bund can be narrow or broad based. Spacing and cross section of bund depends mainly on slope, soil type, rainfall and cropping pattern.

ROOF WATER HARVESTING

HISTORY

Before the development of gasoline engines and electric motors, water harvesting was fairl; a common practice in a number of arid and semi arid regions. It has been reported that wate harvesting systems in the Negev Desert, which are thought to have been built first, about 400(years ago. These systems involved clearing hillsides to smooth the soil and increase runoff and then building contour ditches to collect the water and carry it to low lying fields where water was used to irrigate crops.

In terms of recent history, collection and storage of runoff from treated catchments was developed by using various materials like steel sheets, concrete blocks, plastic and artificial rubber membranes etc. In 1961, the United States of America adopted entirely different approach to the problem and investigated the methods of utilizing the soil itself as the catchment structure. Sprayable asphaltic compounds, plastic and metal films bounded to the soil, soil compaction and dispersion and field fabricated asphalt fibreglass membrane materials were found to be promising, causing Soil to become hydrophobic or water repellent.

The concept of water harvesting is not new to India. Water harvesting has been a traditional practice from natural catchments in arid and semi arid zones, in form of dugout or impounding type of ponds and under different land use. However, no sizable work on water harvesting from treated catchment have been initiated in our country. Several examples on water harvesting from natural catchments are visible, such as, intercepting and diverting of roadside culvert outflow for raising crops in the Hirakud catchment area in Orissa, Low earthen check buttresse of loose boulder pitching for diverting the flow into pickup channels and then into irrigated fields, collecting water by constructing the earthen bund across the slope in the form of Khadins and dugout tanks (Nadis) in Rajasthan etc. Only after 1970, efforts have been made by various research Institute such as CAZRI - Jodhpur, CRIDA - -Hyderabad, ICRISAT - Hyderabad, CSWCRTI - Dehra Doon, to carry out some experiment on various treatment materials for inducement of runoff. However, their application and efficiency on wider scale in fields is to be tested. The high limitation to the use of treated catchments have been the cost per unit of water produced.

STRUCTURAL COMPONENTS OF ROOF WATER HARVESTING

i) Roof Catchment

In this system, only roof top is the catchment. The roofings should be of CGI or Asbestos tiles or concrete. In case of thatch-roof, it may be covered with water proof LDPE Sheeting.

ii) Gutter & Down Pipe

This is the collecting drain provided along the edge of the roof. Gutter is fixed with a gentle slope towards the down pipe for free flow of water. This may be made up of GI sheet, wood, bamboo or any other locally available materials. The down pipe is provided in the Gutter and connected with the inlet of the storage tank. At the junction of the gutter and the downpipe a Jali is provided to prevent entry of foreign material into the Tank.

iii) Foul Flush System

In order to prevent the entry of birds dropping, leaves, etc. into the storage tank, arrangement is made to divert the first few minutes flush of water away from the tank. This is achieved by providing a movable canvas pipe connection between two points. The other method is by making an inbuilt stopper for stopping water entry in the filter and conveying the water into a byepass pipe carrying water outside the system.

iv) Filter

This is provided between down pipe and the Storage Tank. Filter materials such as Sand, gravel or coconut/palm/betalnut fibre, etc. are used as filter media. To support the filter materials, G.I. Sheet R.C.C. or ferro cement are used.

v) Storage Tank

This is the major component of the system used for collecting and storing rain water during monsoon to be used during the dry period. It can be constructed under ground or above ground. The underground tank may be masonary or R.C.C. structure suitably lined with water proofing materials. The surface tank may be of G.I. Sheet, R.C.C., Plastic/HDP or Ferrocement Tank placed at a little higher elevation on a raised platform. To facilitate cleaning of the tank, an outlet pipe with above may be fitted and fixed in the tank at bottom level. The size of the tank will depend upon the factors such as daily demand, duration of dry spell, catchment area and rainfall.

vi) **Withdrawal Arrangement**

The withdrawal of water from the underground tank is made by installing hand pumps in it. In case of surface tank, taps are fitted in the tank.

vii) **Disinfection**

Before the tank is put into use it is thoroughly disinfected with higher dosage of chlorine. Since the water shall remain stored quite for a long time, periodical disinfection of stored water is essential to prevent growth of pathogenic bacteria.

WATER HARVESTING FROM NATURAL SURFACES FOR SURFACE STORAGE AND GROUND WATER RECHARGE

INTRODUCTION

In the driest zone of the world, runoff from granite outcrops, sandstone rock slopes or slick rock hillsides is colelcted by means of low concrete or masonry wells or gutters built around the lower slopes of the rock. The water so collected, is conducted along the gutter to a concrete storage tank built on or close to the rock, or to an earth tank sited downslopes from the rock. The water from these rock catchments is noted for its excellent quality. This system of water harvesting is being followed since time immemorial in the deserts all over the world and serves as an excellent source of water.

PREVALENCE

This system of water harvesting is prevailing in the rocky terrain of Jaisalmer, Barmer and Jodhpur districts in the western Rajasthan. The system is widely practiced in the deserts of Australia, China and U.S.A.

ABANDONED QUARRIES FOR WATER RESOURCES DEVELOPMENT

INTRODUCTION

Nearly 5000 km^2 area in Rajasthan is under mining acitvity. The quarrying for building stones like sandstone, limestone, phyllite. slates, etc. are generally undertaken on hillslopes and most of the quarry pits are abandoned after surface mining. These pits can be used to develop additional water resources both as surface storage and enhanced ground water recharge.

PREVALENCE

Quarrying of building stones is prevailing in and around the Aravalli mountain system and in the western Rajasthan. These areas also have the abandoned pits and mine spoils which can be developed into water bodies.

ROADED CATACHMENTS FOR MAXIMUM RUNOFF

To provide reliable runoff, a water harvesting catchment needs to be impermeable, smooth and have little depression storage. However, sealing the soil surface is expensive and some infiltration losses must frequently be accepted. In these cases, ground forming can increase the runôff yield by improving the hydraulic efficiency of the catchments and thus reduce the time available for infiltration to take plaçe.

One type of formed catchment that is widely used in western Australia and to a lesser extent in other states, is so called roaded catchment. This consist of a series of parallel formed and compacted roads with exaggerated camber that adjoin to make approximately V-shaped channels which discharge into a collecting drain at their lower end. Cambered steeply road surface is made as smooth and impervious as possible. Drains between the roads are on grades that permit water to reach the storage structure expeditiously with minimum erosion.

Site selected should not be more than 400 m far away from the water storage structure and also should consist of clay soil or clay sub soil within not more than 1 m of the surface. (Loose sands and gravels, loams and friable self mulching clays are unsuitable materials for surfacing catchments). Also the surface slope that allows the catchment drains to bealined on correct grades.

EVAPORATION CONTROL

In Indian desert, harvessing and storing rainwater in existing storage facilities is still the major source of water supplies for human and livestock consumption. Evaporation of this water from open water surfaces is very high. The annual average evaporation in this area ranges from 3437 mm at Jodhpur to 2809 mm at Ahmadabad and several times greater than the annual precipitation of the area. Reducing evaporation losses is desirable for maintaining dependable good quality water supplies for a longer period.

The process of evaporation requires both a source of energy to vaporized the water and a transfer mechanizm such as dry air and wind. Reduction in evaporation can be achieved by reducing energy available for evaporation. Solar energy entering the water is usually reduced by suspending a shade above the surface, reflecting more of the incoming solar radiation than does a natural water surface, or by a combination of the above. Wind baffles places around on, or above the water surface have been used to reduce the transport of water vapour.

India has been divided into 11 agro-climatic zones based on moisture and thermal regimes, topography, soil types & crops grown in the region.

1. Humid North Western Himalayas & Himalayan Foot Hills

It covers parts of Jammu & Kashmir, Himachal Pradesh, hilly ranges of Uttar Pradesh, Punjab, Haryana, Bihar, West Bengal and Sikkim having sub-humid climate with annual rain-fall of 750 to 1500 mm occuring in 50 to 75 rainy days annually. The mean temperature ranges from 13°C in January to 27°C in monsoon season. The annual potential evapotranspiration is between 1200 to 1400 mm.

2. Humid high rain-fall North-Eastern Zone

It covers Arunachal pradesh, Nagaland, Mizoram, Manipur, Meghalaya & some parts of Assam having humid to sub humid climates with rain fall ranging annually from 2000 to 2500 mm occuring in 100 to 150 rainy days. The mean temperature ranges from15°C in January to 28°C in monsoon season. The annual potential evapotranspiration is less than 1200 mm.

3. **Humid Assam Bengal Plains & Chotta Nagpur Plateau**

It covers plain areas of Assam and West Bengal, hilly regions of Bihar and Eastern Uttar Pradesh having per humid to sub-humid climate. The average annual rainfall is 1250 to 2000 mm received in 60 to 125 rainy days. The mean temperature ranges from 15°C in January to 30°C in July with an annual potential evapotranspiration in between 1100 to 1500 mm.

4. **Sub-humid and humid Satluj-Ganga Zone**

It covers plain areas of Punjab, Haryana, Uttar Pradesh and Bihar having sub-humid alluvial zone. This zone receives 750 to 1250 mm of annual rainfall in 30 to 50 rainy days. The mean temperature ranges from 12.5°C in January to 32.5°C in July with an annual potential evapotranspiration between 1200 to 1500 mm.

5. **North-Western Semi-arid and Arid Zone**

This zone covers arid areas of Punjab, Haryana, Rajasthan and Gujarat with annual rainfall less than 750 mm in less than 30 rainy days. The mean temperature varies from 15°C in January to 35°C in July. The annual potential evapotranspiration is between 1500 to 2000 mm.

6. **Western Malabar Coastal Zone**

It covers western coast of Kerala, parts of Maharashtra and Karnataka. The climate is sub-humid to prehumid with an annual rainfall between 750 to 2500 mm received in 50 to 150 rainy days. The mean temperature ranges between 22 to 30°C with annual potential of evapotranspiration between 1400 to 1600 mm.

7. **South-eastern Coromandal Zone**

It covers parts of Tamil Nadu, Andhra Pradesh, Karnataka having semi-arid climate. This zone receives 500 to 1000 mm rainfall anually in 40 to 60 days. The mean temperature varies between 23°C to 30°C with an annual potential of evapotranspiration between 1500 to 2000 mm.

8. **Southern Variable rain-fall Zone**

It covers parts of Southern Andhra Pradesh, Tamil Nadu and Karnataka with widely spread semi-arid tract. The annual rain-fall received is 500 to 1000 mm in 30 to 50 rainy days. The mean temperature varies from 22.5°C in January to 30°C in monsoon season. The annual potential of evapotranspiration is between 1600 to 1800 mm.

9. **Variable rain-fall plateau zone**

It covers southern Madhya Pradesh, Orissa, Andhra Pradesh, Maharashtra & Karnataka having sub-humid climates. The annual rain-fall ranges between 500 to 1500 mm spread in 40 to 60 rainy days. The mean temperature ranges from 20°C in January to 27.5°C in July. The annual potential of evapotranspiration is between 1400 to 1800 mm.

10. **Central Semi-arid Zone**

This zone covers parts of Northern Madhya Pradesh and Southern Uttar Pradesh havin semi-arid to dry sub-humid climate. The annual rainfall in this zone is 1000 to 1500 mm received in 50 to 75 rainy days. The mean temperature ranges from 17°C in January to 30°C in rainy season. The annual potential evapotranspiration varies between 1400 to 1600 mm.

11. **Islands of Coastal Arabian & Bay of Bengal**

It covers Andaman-Nicobar group of Islands in bay of Bengal and Lakshwadeep & Mini-coy group of Islands in Arabian Sea.

TYPES OF RAIN WATER HARVESTING STRUCTURES IN DIFFERENT AGRO - CLIMATIC ZONES

S. No.	Name of Agro climatic zone	State of the Art	Recommendations
1	2	3	4
1.	Humid North-Western Himalayans & Himalayan foot hills	i) Roof water harvesting ii) Diversion of perennial spring and streams in a storage structures iii) Village Pond iv) Collection from hill slope	Improvement in roof structure and use of proper material such as corrugated sheets, for generating higher run-off and with arrangement of foul flush diversion system and proper storage structure for checking water from contamination
2.	Humid High Rainfall North-Eastern Zones	i) Roof water harvesting ii) Diversion of perennial spring & streams in a storage structure (tank)	- do -
3.	Humid Assam Bengal Plains & Chhota Nagpur plateau	i) Tank ii) Anicut/check dam iii) Gully plugging iv) Contour bunding	Improved design of tank for minimising evaporation and seepage losses, control of sediment load and water pollution
4.	Sub-humid and Humid Satluj Ganga Zone	i) Pond ii) Check dam iii) Gully plugging iv) Contour bunding	- do -
5.	North-western semi-arid & Arid zone	i) Nadi ii) Tanka iii) Khadin iv) Percolation tank v) Anicut	i) Adoption of improved design of Nadi and tanka ii) Sand filled reservoir iii) Sub-surface barrier iv) Flat battern tank

1	2	3	4
		vi) Gully plugging vii) Contour bunding	
6.	Western Malbar Coastal Zone	i) Tank ii) Check dam iii) Percolation tank iv) Contour Bunding v) Underground bhandara vi) K.T. Weirs vii) Sub surface dam	i) Improvement in existing system for better water management ii) Construction of structure at suitable sites
7.	South-Eastern Coromandal zone	i) Pond/tank/kunta ii) Nadi iii) Check dam iv) Percolation tank v) Sub-surface dam vi) Gully plugging	i) Adoption of improved design of Nadi and tank ii) Selection of suitable site and improvement of existing system for better water management
8.	Southern Variable rain-fall zone	i) Pond/tank/kunta ii) Nadi iii) Check dam iv) Percolation tank v) Sub-surface dam vi) Gully plugging	i) Flat battern tank ii) Selection of suitable site and improvement of existing system for better water management
9.	Variable Rain-fall plateau zone	i) Pond ii) Check dam iii) Percolation tank iv) Underground bhandara v) Gully Plugging vi) Sub-surface dam vii) Contour bunding	i) Flat battern tank ii) Selection of suitable site and improvement of existing system for better water management

1	2	3	4
10.	Central semiarid zone	i) Pond ii) Check dam iii) Contour bunding iv) Gully plugging	- do -
11.	Islands of coastal Arabian & Bay of Bengal	i) Roof water harvestings	i) Conjunctive use of ground water & rain water

INTERNATIONAL DRINKING WATER SUPPLY & SANITATION DECADE IN INDIA

A CASE STUDY OF THE POLICIES AND PROBLEMS

BY

G. GHOSH

INTRODUCTION

At Mar Del Plata in 1977 the United Nations Water Conference for the first time separated out drinking water and sanitation from other water issues, suggesting for them the 'Decade' approach - adopt programmes with realistic standards of quality and quantity to provide water for urban and rural areas by 1990, if possible. The Conference recommended that each country should 'develop national plans and programmes for community water supply and sanitation..... giving priority to the segments of the population in greatest need'. India was also a signatory to the resolution seeking to achieve the targets by 1990. Consequently the Water Decade Programme was launched in India on 1st April, 1981 with a view to achieve definite targets of coverage of population by 31st March, 1991. Reviewing the status, at the beginning of the Decade in India, protected water supply facilities were available to 77 per cent of the urban population and 31 per cent of the rural population which compares favourably with the figures for developing countries which according to WHO were 75 per cent and 29 per cent respectively. However, in the field of sanitation against the figures of developing countries of 53 per cent coverage, India had only 27 percent in urban areas and a mere 0.5 per cent coverage in rural areas until the beginning of the Decade.

STATUS REPORT

Against the backdrop of progress already made in the last 30 years through the various plans and bearing in mind the mandate of the IDWSSD, it was necessary to delineate targets which would be realistic and could be considered attainable during the Decade, stretching all the possible resources to the maximum.

A considerable amount of exercise had to be made at various technical and administrative levels and as a consequence, the following targets had been recommended for the Decade :-

1.	Urban and rural water supply	:	100% of the population
2.	Urban sewerage and sanitation	:	Overall coverage of 80% of urban population by means of sewerage and simple sanitary methods of disposal
3.	Rural sanitation	:	25% of the population to be provided with sanitary toilets.

While drawing up and implementing the Decade programme a list of priorities were drawn up :-

(a) Safe drinking water to problem villages;
(b) Safe drinking water to uncovered towns or uncovered urban areas;
(c) Low cost sanitation to towns other than class I;
(d) Rehabilitation of urban water supply;
(e) Safe water supply to non-problem villages;
(f) Augmentation of urban water supply systems;
(g) Sewerage facilities to class I cities lacking them at present; and
(h) Sanitation in rural areas.

The **Problem Villages** have been identified as per the following criteria :

(i) No source of water is available within 1.6 Kms distance, 100 metres of elevation difference or available water is at a depth of more than 15m.

(ii) Biological contamination of the source of water.

(iii) Chemical contamination of the source of water with chemicals such as fluoride, brackishness and iron etc.

At the start of the Decade programme, 362 millions of rural population and 33 millions of urban population were without any supply of safe drinking water. As regards sanitation, the problem is even more severe, as 521 million in rural areas and 108 million in urban areas were without adequate and sanitary means of human excreta disposal.

To achieve the Decade goal, the estimated cost of investment required was US $ 10.49 billion at 1980 price level with the follwing break up :-

Urban water supply	US $ 2.34 billion
Rural water supply	US $ 4.72 billion
Urban sanitation	US $ 2.77 billion
Rural sanitation	US $ 0.66 billion
	US $ 10.49 billion

Recognising the need for coordinated action and approach and to achieve the decade goals, the Government of India constituted an Apex Committee. the Apex Committee constituted three working groups (i) Financial Resources; (ii) Materials and equipment and (iii) Programmes and manpower. These working groups came out with a number of suggestions/recommendations which were approved by the Apex Committee and All India Conferences of Central and State Governments.

The levels of service to be provided in the various sub-sectors were :-

Urban water supply	70 - 250 LPCD, average 140 LPCD, 25 - 70 LPCD by standposts with piped water supply in all communities with an average of 40 LPCD.
Rural water supply	Piped water supply to 30% of the population with 25-70 LPCD with an average 40 LPCD, spot sources to 70% of population with an average supply of 40 LPCD.
Urban sanitation	100% coverage of class I cities with sewerage, sewage treatment and overall coverage 80% in all cities with low cost sanitation.
Rural sanitation	Low cost sanitary method of disposal for 25% of population

ACHIEVEMENTS

In India IDWSSD programme has been divided into two phases. The phase I of the programme which culminated with VI National Five Years Development Plan, excluding its 1st year of inception, i.e. 1980-81, had recorded an expenditure as given below :-

(i)	Urban water supply	US $ 0.67 billion
(ii)	Rural water supply	US $ 1.63 billion
(iii)	Urban sanitation	US $ 0.15 billion
(iv)	Rural sanitation	US $ 0.02 billion

The achievements by the end of Ist phase of Decade Plan (ending on 31.3.85) are as follows :

Table 1

Category	Population served (in millions)				Diff (81-85 +/-%)
	1981		1985		
	Popn	%	Popn	%	
Water Supply					
Urban	115.48	72.3	127.23	72.9	+ 0.6
Rural Sanitation	162.07	30.8	313.56	56.2	+ 25.4
Urban	40.08	25.1	49.56	28.4	+ 3.3
Rural	2.80	0.5	4.03	0.72	+ 0.22

Unfortunately, India is one of those countries which register high population growth rate (present birth rate is 2.5). Hence the real achievements in respect of population coverages are much more than that reported as increase in population during the period have been taken care in the coverage made specially with respect to urban water supply and sanitation programme. The impact is very low. Sizable achievements however have been shown with respect to Rural Water Supply Programme yet not to satisfactory level.

During VII National Five Year Development Plan (1985-90), an outlay of US $ 14.73 billion was proposed for the water supply and sanitation sector to achieve the Decade objectives by March, 1991. However, in view of the resource constraints, the National Development

Council (NDC) approved an outlay of only US $ 4.83 billion for the sector for the VII Five Year Plan.

As a result of this reduced outlay, the Mid Decade Review in Urban Sector scaled down the targets as follows :-

Urban water supply	90%
Urban sanitation	50%

In the rural water supply sector the country faced with repeated and severe drought resulting in break down of the established system. In order to give a boost to rural water supply sector Government of India in September, 1985 decided to shift the subject from Ministry of Urban Developmentto Department of Rural Development in Ministry of Agriculture. The concept was to integrate the rural water supply sanitation programme with the rural development and employment with agricultural development.

In 1986, a further input has been given to rural water supply with the launching of National Drinking Technology Mission with an objective of coverage of the whole country by 1990 with safe drinking water supply in rural areas. While launching the Mission Shri Rajiv Gandhi, Prime Minister of India said in Parliaent in April, 1986, "We have decided on a number of missions already. Five have already been established. Drinking water - it might sound simple that we will just be digging holes in the ground and pulling water, but out of all these five missions, the maximum amount of scientific development and technological development will go into drinking water, and the highest technology out of any of these missions will be used to give drinking water specially in those areas where there is a tremedous shortage of drinking water."

Looking to the achievements made so far and funds available within the sector, and with launching of Technology Mission it was not felt necessary to scale down the target of Rural Water Supply, however, with respect to rural sanitation not much action was possible due to various reasons including finance.

The achievements reported till 31.3.87 in Urban Water Supply and Sanitation and till 31.3.88 in Rural Water Supply and Sanitation sub-sectors are as follows :-

	Population coverage	Percentage
Urban water supply	146.23 million	79.24%
Rural water supply	390.50 million	74.32%
Urban sanitation	74.51 million	40.37%
Rural sanitation	8.03 million	1.44%

MAJOR SECTOR ISSUES AND MEASURES TAKEN

There is no point in offering a technology to the poor which is inappropriate because the poor will be unable to afford or maintain it. In India, two most important aspects for development are - the socio-political will and availability of the know-how and the technology at the grass root level to bring about improvements. All the State Governments and particularly the Union Government are committed to rural drinking water supply and a national programme to that effect has since been launched. Drinking water is also one of the 20 points of Development plan of the Country closely followed and monitored by Government of India.

The major constraints in the implementation of rural water supply programme was not due to the non-availability of water but were :-

(i) Institutional

(ii) Human resources

(iii) Operation and maintenance inadequacies

(iv) Water resources management

(v) Imbalance between urban and rural areas

(vi) Non-involvement of community

(vii) Urban oriented technology

(viii) Absence of integrated approach

(ix) Inadequate finance

(x) Slow progress of Decade and national programme on rural water supply

(xi) Absence of systematic MIS base

Realising the above constraints, Goverment of India with a strong political will in providing this basic need to the rural population, made (during September 1985) Department of Rural Development, Ministry of Agriculture, responsible for Rural Water Supply and Sanitation at the Central level. The Department has, since 1985, propagated for three objectives - (i) cost reduction; (ii) time target achievement and (iii) appropriate technology mix.

The **National Drinking Water Technology Mission** was set up in early 1986 with the Department of Rural Development as the nodal department. It was one of the five Natinal Societal Missions to develop and implement the programme on a scientific basis to solve the problem of safe drinking water in the country by 1990. The Technology Mission mobilised resources of national scientific institutions, water supply authorities and various experts and Government departments on a priority basis to study the problems at grassroot level to evaluate cost effective solutions, to ensure supply of adequate and acceptable quality of drinking water on a sustained basis. Main theme of Water Mission are :-

(a) To adopt Scientific source finding and development.

(b) To lay emphasis on Water harvesting and conservation of water.

(c) Introduce new rigs and equipment for water prospecting.

(d) To bring about a new Dimensions by Application of Science and Technology inputs in an integrated manner for generating cost effective long term solutions to predominant problems associated with rural water supply.

(e) To give importance to a computerised Management Information System (MIS) for collection of data, analysis, monitoring and evaluation.

(f) To link up all the technological improvement to the ultimate goal of improvement of life of an ordinary villager and to involve him/her in the process.

The Mission identified 5 areas of immediate concern and accordingly 5 sub-Missions have been set up. Some operational targets of these sub-Missions include :-

1. **Conservation of water** and recharging of aquifers by providing remote sensing technique followed by hydrological and geophysical survey with participation of different national scientific organisations in areas where no sustained water source is available.

2. **Eradication of guineaworm** in 8811 villages by 1990.

3. Control of fluorosis in 8700 villages by application of appropriate technological inputs like Nalgonda technique.

4. Control of brackishness in 17500 villages by reduction to tolerable limits by application of appropriate technology such as reverse osmosis, electro-dialysis, solar stills etc. with the participation of various national scientific instituions/organisations.

5. Removal of excess iron in 2900 villages to tolerable limits by application of appropriate technological inputs.

The problems of supplying drinking water in the villages are many and vary from region to region. The Geological variation in India is so much that the techniques of watertargetting vary also. Based on the problems associated with the supply of drinking water, 55 Mini Mission Project areas have been identified. The strategy would be to evolve models and cost effective Science and Technology technqiues which can be easily replicated and incorporated in the on going programmes.

Continuous monitoring of water quality has been considered to be the most important activity to be adopted all over the country. Efforts are being made to establish stationary and mobile laboratories and training of laboratory technicians. Portable water analysis kits have been developed for on the spot tests. Manuals required for the same have been prepared.

The Technology Mission approach been able to come across the following deficiencies, which were earlier identified in the Rural water Supply Programme :

1. Less emphasis on the water quality testing.

2. Lack of treatment of water affected with excess chemical or bacterological contamination.

3. Absence of an appropriate science and technology input to increase efficiency of performance, to secure reduction of the cost, in devicing delivery system which are more efficient by reducing the energy cost and material cost etc.

4. Almost total lack of involvement of the community in the whole system.

5. Less emphasis on water harvesting and conservation of water and on ground water management for drinking water supply.

6. Reluctance of an integrated and disciplinary approach.

In India, Decade Programme is no longer interpreted merely in terms of physical targets and more finances, but more importantly as an opportunity to carry out much needed reforms in strategy, planning, implementation, monitoring, operation and maintenance, community participation of rural water supply and sanitation projects in the mid decade period.

In the field of Urban Water Supply and Sanitation, the existing know-how of implementing piped water supply and sanitation methods with the available financial resources was carried out. The working group on Financial Resources an subsequently the Mid-Decade Review Conference identified that out of all the constraints, the mobilisation of adequate financial resources, for implementation of Urban Water supply and Sanitation is the major one. Considering the inadequacy of budgetary resources and constraint of finances through traditional channels, it is proposed to set up a financing institution for urban infrastructure specially for water supply and sanitation at the National Level. When this financing institution is set up, it would be able to raise considerable finances through instiutions and by floating of debentures. The Life Insurance Corporation of India (LIC) has now simplified the procedure for processing applications for loans of water supply and sewerage schemes of the states. Similarly Housing and Urban Development Corporation (HUDCO) is also giving loans for low cost sanitation schemes of all urban communities at lower interest rate of 6%. They have also simplified the procedure for processing the loan application.

Similarly in the field of Rural sanitation, due to non-availability of adequate financial provisions, other Rural Development Programmes were roped together to provide maximum benefits to the poor population. However, the coverage is far from the target. The main reasons behind less coverage, apart from finance have been inadequate are lack of health education, non-existing motivation, improper implementing agency and lack of delivery system to carryout the programme at grassroot level. All these factors are looked into in a greater detail at present at the highest level and an action plan for an integrated approach is one the anvil to be launched shortly. However it has been concluded that sanitation cannot be a Government sponsored programme like rural water supply and has to be a people's programme with Information, Educaiton and Commuication (IEC) support to the Government.

EXPERIENCES GATHERED

The adoption and approach of project management with introduction of inputs of managerial techniques as well as necessary hardwares has shown that even in the difficult situation like repeated droughts the country can solve the problem of drinking water supply within a definite time frame work. The experiences of Technology Mission in India has also shown that the capital cost can be reduced to the extent of 25 to 30 per cent or even more if the programme is planned in a project form and implemented in time. It is also essential to have an integrated approach towards water supply programme particularly in the rural areas which is different from the standard treatment and delivery approach in the urban areas where mostly the source is dependent on the surface water. The emphasis is also more on the distribution system in the urban areas than the rural areas. The cost can definitely be reduced if a project is planned to emphasis on the spot sources rather than a piped water distribution system. This also takes care of the problem of supply of energy in the developing countries. A low cost water supply system with the involvement of the community and supplemented by rain water harvesting and improvement of traditional structures can go a long way in arid and semi-arid regions and hard work areas. Sufficient input of geology and geohydrology is required for development of sources and a supportive water surveillance system is necessary to maintain the quality of supply. It is also necessary to emphasise on health education and sanitation. However, several studies have shown that the rural women emphasise the need of water supply first and then only sanitation as their felt need. The new emphasis on the rural sanitation in India will justify that a different strategy is required then the water supply in this sector. The rural sanitation in India can be a totally people's programme with Government's role restricted to promotion of agencies, improvement of delivery system and supply of appropriate technology. In fact rural sanitation is more complex and difficult programme than rural water supply. The same is true for urban area also.

FUTURE STRATEGY

Rural Water Supply

The Rural Water Supply was so far developed as an exploitative delivery system. The thrust has to change towards an integrated approach of the subject through a large number of disciplines which would include geologist, hydrogeololsists, geophysicists, public health engineers, civil engineers, environmentalists, irrigation engineers, agricultural scientistists and above all social scientists. The Rural Water Supply is not merely a hardware oriented programme. A massive social awareness campaign for the investment of people as well as development of awareness of water as a scarce commodity and not necessarily a renewable reosurce and the necessity of having a safe water for health and other purposes should be launched.

Rural Sanitation

In the field of Rural Sanitation the main elements of strategy are :

A. Promotion of total concept of sanitation amongst the people. This will include environmental sanitation, personal, home, food hygiene, solid waste disposal and waste water disposal etc.

B. Sanitation cells created in the State, Districts as well as Block level.

C. Intensive programme of rural sanitation in certain selected districts in the 1st phase, which could be replicated in other districts of the State in the next phase.

D. Development of the Delivery System is of prime importance. In fact the development of software will get more attention than the hardware. Once people understand the importance of the subject through motivation and health education there would not be any difficulty in accepting the hardware provided.

E. As availability of finance for the implementation of programme may not be easy we have to go in for institutional loan for agencies/beneficiaries.

Urban water supply/sanitation

In cities, the affluent sections of the urban population which can afford should wherever possible be provided with house connections with full cost recovery. However, for the economically weaker sections in urban fringe areas, standposts should be provided at strategic locations with provision of community sanitation facilities. The water supply to uncovered towns should also receive high priority and rehabilitation of urban water supply systems should receive serious consideration, since in many of the urban communities the systems have deteriorated due to age and usage.

According to the Decade programme revised targets, the class I cities will be provided with sewerage and sewage treatment facilities. However, in the fringe areas of these cities, community toilets have to be provided. Moreover, in areas where sewerage systems are not possible to develop, low cost sanitation methods of two pit pour flush latrines have to be adopted. Class II to Class VI cities would, however, must be provided with low cost sanitation facilities only. Thus, overall coverage of urban population by all methods of sanitation facilities would be 50% of the total urban population by 31 March, 1991.

Peri-urban areas

Due to the fast growth rate of the urban centres (40 to 50% in certain cases) in the rural areas, problem of water supply and sanitation has got indirectly increased. In these areas unless there is sufficient water supply, proper sewerage system cannot be developed and for the development of the same, adequate space is required which is a constraint. As the sewerage system cannot be developed easily the piped water supply provided results in stagnation of water and a crisis situation for health and sanitation. Govt. of India has decided that all the urban pockets of 20,000 and below in 1981 census irrespective of fact whether they are declared as urban areas or municipal area would be tackled by Department of Rural Development through low cost water supply and sanitation. The water supply and sanitation problem will be handled in the same low cost technology approach as in rural areas. Repeated droughts have shown that the entire emphasis has been shifted from surface water to the management of underground water in such areas and these urban pockets survived because of well developed ground water. The spot source supply also reduces the cost. A study has been adopted in those areas where deep tubewells have been developed for water to be supplied through public standposts or house connections and in such cases the waste water is diverted to some more useful purposes like afforestation on the outskirts of the towns. It is very clear that the real problem in future will be faced by these areas where lack of adequate finance as well as lack of cost recovery would create a situation if high cost approach is introduced. One of the major emphasis in the coming years will be to tackle water problem in such areas through a conjunctive use of both surface and groundwater and a low cost sanitation approach.

DROUGHT MANAGEMENT

One of the problem faced by India in the decade is the repetitive nature of drought in most parts of the country. In spite of the same the country is poised for a 100% coverage of rural population by safe drinking water supply due to the technology base and the Socio-Political structure.

Government of India has a well oiled drought combating machinery where Crisis Management Groups (CMG) including all concerned ministries and scientific institutes are involved by Ministry of Agriculture. Department of Rural Development through its National Drinking Water Technology Mission (NDWM) coordinates a Sub Group on water which consist of Indian Metereological Department (IMD), Central Water Commission (CWC), Central Groundwater Board (CGWB), National Institute of Hydrology (NIH), Ministry of Urban Development (MUD) and DRD. NDWM also coordinates all activities of both rural and urban area, monitors the situation periodically and reports to a Subcommittee of Cabinet of Ministers chaired by the Prime Minister himself.

Master plan are prepared for both short term as well as long term basis and advance actions taken for :

1. Conservation of water through spraying of Cetyl alcohol, Compartmentalisationof dam etc.

2. Restriction of use of water for industries.

3. Encouragement of recycling of water Desalination technology and use of Waste Water for construction and other purposes.

4. Rejuvenation of defunct tubewells.
5. Creation of employment through construction of Water Harvesting Structures.
6. Development and judicious use of ground water even for urban areas.
7. Improvement of distribution system as far as possible.

UNICEF helped the Government in procuring all terrain rigs, heavy duty combination rigs as well as other survey equipments. Most DTH and Combination rigs being available in the country, Government of India also purchased a large number of them and gave to State Governments. Utilisation and movement of such rigs are closely monitored through computerised rig monitoring system. Nearly 100,000 boreholes were specially dug to combat the drought last year. Inspite of such a large figure and possibly the largest operation in the world the failure rate was only 5% on an average. Groundwater level was monitored for nearly 12000 points (observation wells) all over the country. Conjunctive models of surface and ground water are being developed in seven basins to find out the water balance. Among various R & D programmes launched, one was to develop a better evaporation retardant for reduction in evaporation loss.

Inspite of such drought the normal plan programme had been continued and closely monitored. It was a challenge met with efforts by all and excepting in peri-urban or urban areas where health problems cropped up with the heavy rainfall, but the rural area comparatively are safe and in a comfortable position.

NATIONAL WATER POLICY

The requirement for drinking water purpsoes vary little. A survey has shown that in India we require 4 to 5 per cent of total ground water sources and 8 to 10 per cent of surface water sources. In spite of that there is acute drinking water scarcity. A study of the drought has shown that it is not the failure of the monsoon but overdrawal of water due to development of agriculture and urban pockets which creates the imbalance of water supply. The National water Policy accepted by Government of India has given the drinking water supply a top priority. Henceforth in all irrigation projects 10 percent will be reserved for driinking water purposes. However, there is a need of legislation to control the over-exploitation of ground water particularly in certain parts of the country. Unless the over-exploitation of ground water is controlled the equitable distribution of water would not take place and it would create a serious imbalance not only for drinking water but also for developmental purposes. All the State Governments have been requested for introduction of water legislations and positive response has been obtained. However, a massive awareness campaign is necessary for people to understand that water is not necessarily a replenishable commodity. In certain leaking aquifer the exploitation is 170 to 180 per cent and unless we give emphasis on total ecology and environemntal situation, merely exploitationof water through better technology will not help us in the long run. In the next decade possibly the emphasis should be more on not merely supply of drinking water but for an integrated approach towards total water management.

HUMAN RESOURCE DEVELOPMENT

The need of a planned human resource development for rural water supply and sanitation sector is enormous than urban, particularly when the problems are multifarious and the solutions widely varied from mechanical to chemical and biochemical to biotechnologica. Inthe Technology Mission the entire gamut of the scientific community in India got involved in tackling this problem and developing specific solutions for water purification, water treatment, Water recycling and maintenance of hardwares like simple handpumps, trained mechanical engieners, chemical engieners, civil engineers as well as scientists specialists in surface chemistry, biochemistry, biotechnology, geosciences, geophysics, agro-science, space science, Nuclear Science et. were all got involved to achieve the goal. This shows that for a nation wide water supply programme, besides the formal structures of human resource developemnt, there is a necessity to tap all the resources from available national institutions and scientific bodies. The academic institutions can also play a major role in providing additional inputs in both project preparation, implementation and monitoring.

With this in view and with the experiences already gathered Government of India is contemplating to start an integrated Course which would provide the entire facet of the science and engienering and technology available in the country in the area of Public health Engineering as well as provide additional inputs of social communication and training of computerised management systems to water supply and sanitation engineers. Out of 480 districts in the country nearly 50% have been provided with a computerised MIS system and necessary hardwares. Various problems of chemical pollution is being tackled by pollution engineers as well as surface chemists as to improve the life of boreholes as well as piped water system. In the water surveillance programme a large number of chemists, trained analyst are required for continuous water quality monitoring. Besides for a planned human resource development programme the areas which are really being strenthened are inputs of geohydrology and integrated approach towards water management, use of space imageries, geophysics, biological contamination testing and additoinal management inputs in both financial and managerial sides. Various national institions have been identified and certain cases bilateral as well as international donor agencies are being tied up to coordinate and develop such human resource development programmes. But there is a need of development of some specialized institutions exclusively meant for the new thrust of human resource development and this report World Bank and other bilateral agencies can play a major role.

ROLE OF UNITED NATIONS/WORLD BANK AND OTHER DONOR AGENCIES

The national planning process lays down a clear perspective and direction for any programme and a massive finance is available for both Central Government as well as the State Governments for the programme. The donor agencies can play a crucial role in developing in finacial and qualitative terms the bilateral projects which serve as the model project for reapplication. However, monitoring and control of such projects led to a situation where the per capita cost of such proejcts are higher and always it may not be possible for the State Governments to replicate that level of success in other areas without such concentrated inputs. Hence these projects tend to be artificially modelled in certain cases. Yet experiences borrowed has helped the State Governments to modify their regular projects for better purpose. Notable projects are with Dutch assistance, DANIDA, SIDA, FRG assistance, ODA, UK etc. UNICEF has played a very crucial and important role in the country where they not only provide the hardwares through drilling rigs and supportive equipments also taken up a series of KAP (Knowledge, Attitude and Practice) studies as well as programmes which involves the comunity participation particularly in the areas of rural sanitation.

Although World Bank had not taken up rural water supply projects so far, during last drought it had specially come forward to start programmes in areas like Gujarat to tackle the rural water supply problems. It is true that in the present philosophy, the cost recovery for rural water supply in Bank projects might be difficult but in rural sanitation as well as in certain specific project areas of rural water supply projects under Bank it would be useful and definitely show new directions to the areas of community maintenance and cost recovery. In fact, the rural India provides a unique scope of development of integrated projects where because of existence of a strong rural development programme, activities under health, education, afforestation, water conservation and drinking water supply can be coordinated and can be the model projects in near future. The prupose of geological conditions and physiographical variations also provide experimentation with different types of projects and with different target groups. the proposed Regional Advisory Group of World Bank would possibly play a significant role towards this direction of increased role of World Bank in Rural Water Supply and Sanitation.

HEALTH EDUCATION AND COMMUNITY PARTICIPANTS

Having realised the important role of Health Education and Community Participation in the development of water supply and sanitation sector in the ocuntry, a Working Group was constituted in 1984 which came out with certain recommendations which required concentrated attention. They are :

1. Health education component relating to water supply and sanitation should be reinforced in the curriculum of health workers. Apart from this, Gram sewak, Agriculture Assistants, Village level workers, teachers, pump mistries and TRYSEM workers should also be trained on priority basis.

2. To supplement the programme of Health Education and community participation a media material is essential. These could be developed by NGO/voluntary organisation in the form of models, puppet shows, posters, slides, films etc. which could be used by general public and target group. NGO/voluntary organisation had been provided with adequate support for the same. Nearly 140 such agencies have been involved in Technology Mission.

3. Community involvement must be obtained right from the beginning of the programme. Community involvement may be obtained in the form of labour, land, donation, helping maintenance facilities etc.

4. Inter-sectoral coordination between Health Department and Agriculture, Rural Development, Social Welfare, Education, Public Health Engineering and Municipal administration should be brought by involving their workers at peripheral level to carry out health education.

5. To provide health education in school going children, the teachers should be adequately trained and involved.

6. The role of women in health education and community participation is very vital, Thrust should be given to educate them on health aspects. Women voluntary organisations should be actively involved in the programme.

Implementation of each of these activities require elaborate planning involving a large number of organisation and co-ordination with different activities. Most of them are time consuming, decentralised and hence slowly being picked up by the implementing agencies of the States. Hence Mission approach achieves significance as it was possible to start implementing such integrated schemes.

OPERATION AND MAINTENANCE

Water Mission in the country has emphasised that unless the facilities already created and those to be provided under the Mission are properly maintained and operated the very objective of the Water Mission would be defeated. Moreover, the investment of scarce resource in the construction phase would be wasteful without operation and maintenance.

A number of operation and maintenance problems have been observed in Water Supply and Sanitation programme. They are :

A. Inadequate finance.

B. Complexity in operation and miantneance.

C. Absence of viable and suitable maintenance system and organisation.

D. Absence of suitable preventive maintenance concept.

E. Inadequate in service training and non-availability of required trained manpower.

F. Lack of collective, compilation and interpretation of base data and maintenance concept.

G. Absence of adequate appreciation and involvement of community particularly the users.

H. General Apathy in the part of implementing agency to carry out new works to achieve the targets set than to operate and maintain the existing systems at the desired level.

All these points raised above require deep thinking and proper action at all levels specially in the State, District and Block level. A decentralised handpump monitoring system based on the Kardex System of monitoring is also proposed to be extended to all States.

To improve upon financial aspect of operation and maintenance Government of India has decided that of the total funds released to the States under Centrally Sponsored Accelerated Rural Water Supply Programme upto 10% may be utilised for operation and maintenance of assets created. The States are also supposed to provide matching grant under State Sector MNP subject to the approved norms. It has also be decided that there should be specific incentives as well as disincentives for proper maintenance of drinking water.

In the urban areas, the operation and maitenance of the system developed mostly lie with the local bodies which are generally financially very poor and solely depends on the subsidaries of the State Governments. The tariff structure is mostly inadequate to meet the basic O & M charges. It was, therefore, necessary to extend financial assistance for operation and maintenance.

MANAGEMENT INFORMATION SYSTEM

The Technology Mission had asked all the State Departments/Boards dealing with Rural Water Supply Programme to introduce computerised Management Information System for rural drinking water programmes in india. In general the data files which have to be covered by the MIS system are :

(a) Coverage of villages and popualtion;

(b) Water resources;

(c) Material and manpower resources:

(d) Financial data;

(e) Profiles on problem villages.

The Technology Mission has identified the following main field for application of the MIS system :-

1. Storage and retrieval of data;
2. Project planning and appraisal;
3. Monitoring and concurrent evaluation.

Computers have bene provided to all the implementing agencies. Data collection has already been started and software are being finalised. The MIS system thus developed includes level of reporting and direct information flow from the field level to Central and State Headquarters. regular training had been organised and concurrent evlauation had been conducted with the help of 30 non-Government agencies to give report on the Status of water supply system developed.

Similarly monitoring of urban water supply and sanitation programme software are being developed for field application.

SOCIO BEHAVIOURIAL ASPECTS

It has often been observed that any hardware provided in the rural areas, without really bothering for the software component, goes mostly as waste because of the following reasons :

(i) People do not accept the system as their own;

(ii) People do not make use of the system in the optimum extent, sometimes due to lack of demystefication;

(iii) Operation and maintenance of the system are bad; and

(iv) Community does not come out for participation in implementation, operation and maintenance of the systems developed for them.

The present programme is to bridge the communication gap that has been created through motivation, visual and posters etc. NGOs have also been appointed to implement the programme including Geophysical surveys, project preparation, drilling, setting up of desalination plants etc.

FINANCIAL ASPECTS

Community water supply and waste water collection programmes has to compete with a wide variety of other public infrastructure and productive capital projects in securing investment finance from national and international sources. Most governments in developing countries are short of fiscal resources for development and both water supply and more particularly sanitation, have traditionally recieved low priority in the sectoral scramble for funds. Consequently, there has been a considerable under investment in these basic facilities, which has been rectified to some extent since launching of the Decade Programme.

In general, water supply schemes are better placed than waste water disposal. Moreover, waster supply scheme generate revenue whereas the waste water disposal do not have an identifiable and saleable product but rather represents a community service. Moreover the waste waters systems are generally more capital intensive. Hence financing these system and paying for their subsequent operation is therefore often problematical.

In India, the National Government has shown adequate interest in the rural water supply sector and thereby given highest priority in national plans. As rural sanitation demonstrate low financial viability than water supply, the national plans have to show more flexible attitude than that in the case of water supply. However more than the financial allocation a strong Socio-Political will is a must in any such programme.

Urban water supply, in most cases with sound financial management, should be able to pay for recovering operationg and financing cost. The tariff structure should be adequate, fair, simple and enforceable. Though it is not possible to incorporate all these aspects, but trade off may have to be made between them.

In case of rural water supply and sanitation in India, all investment made is from the Government's side. However, it is now felt that the villages should have the operation and maintenance changes to the maixmum extent possible, but for doing so the community should be involved totally in the programme, contribute in the programme and also maintain the same.

CONCLUSION

Projects of water supply and sanitation has to be implemented on an integrated fashion closely coordinated with health, agriculture, minor irrigation and other rural development programmes. With more demand of water an approval of total water management has to be adopted. In urban areas also the close linkage with the Health programmes and of the Women and Child Welfare programmes cannot be neglected. Any country has to spell out its national policy in a clear cut fashion and has to give water supply and sanitation a top priority. Improved water supply and sanitation conditions will in general improve the health of the children and women who should be the target audience for the programme and communication.

The international donor bodies can act as catalyst of information as well as supply crucial hardware, provide forums for global exchanges and give the programme an international cooperative approach. Seminars in zonal cooperation and mutual exchanges of experiences as well as experiments of development of low cost models should be encouraged. Consolidation has to be given top priority now and people's participation should be sought for at every stage. Finance is not a real constraint but project preparation and its management is a crux of the success of the any programme. The decade will not end in 1991 but has to be extended till 2000 with renewed pledge and clearly spell out new priorities, objectives and strategies.

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Annex - I

SUMMARY OF COUNTRY DATA ON

1. Preparation and GNP

a) Population (in Millions)

		1981 Census	Projected 1991
i)	Rural	525.46	608.59
ii)	Urban	159.73	190.55
iii)	Total	685.10	799.14

b) Average growth of population per year

S.No. No.	Sector	1971-81	Projected Decade Growth Rate (1981-89)
i)	Rural	1.97%	1.58%
ii)	Urban	4.66%	1.93%
iii)	Total	2.50%	1.66%

c) Total number of inhabited villages (1981 census) 557137

d) Gross National Product (GNP) at factor cost (Rs. Crores)

	1986-87 (Quick estimates) At current prices	At 1980-81 prices
d) Gross National Product (GNP) at factor cost (Rs. Crores)	259155	161298
e) Net National Product at factor cost (Rs. in Crores)	229035	143935
f) Per capita Net National Product (Rs.)	2974.50	1869.30

2. **Some basic vital and health statistical information**

a)	Exception of life at birth	Male Female	55.6 (1981-86) 56.4 (1981-86)
b)	Crude Birth rate		32.9 (1985)
c)	Crude Death rate		11.8 (1985)
d)	Infant Mortality rate (1981 Census)	Rural Urban Total	107 (1985) 59 (1985) 97 (1985)
e)	Water borne and water related diseases in the country	Diarrhoeal Diseases, Enteric Fever, Viral Hepatitis, Encephalitis, Polio-myelitis Hepminthic Diseases, Endemic Goitre, Dracontiasis (Guineaworm), Fluorosis.	

3. **Institutional Structure (Rural Water Supply and Sanitation)**

		Central	State
a)	Responsible Ministry	Agriculture	Rural Development Panchayati Raj, Health Irrigation, Local, Self Government, Public works
b)	Authority Incharge	Department of Rural Development	Chief Engineers (Rural Water Supply) i) Rural Development Dept. ii) Public Health Engg. Department iii) Panchayati Raj Deptt. iv) Local Self Govt. Engineering Dept.

				v)	Irrigation
				vi)	Public works
c)	Other concerned	i)	Planning Commission	i)	District Rural Dept. Agencies (DRDAs)
		ii)	Department of of Economic Affairs	ii)	Voluntary Agencies Non-Governmental Organisations
		iii)	Council of Scientific and Indus. Research	iii)	Zonal Offices of Central Ground Water Board
		iv)	Ministry of Science & Tech.	iv)	State Ground Water Boards/Department
		v)	Min. of Water Resources	v)	Science and Tech. Institutions
		vi)	Department of Space	vi)	Zonal Laboratories of CSIR
		vii)	Min. of Health & Family Welfare	vii)	State Health, Rural Development, Irrigation, Planning & Finance Department
		viii)	Dept. of Environ. & Forest		
		ix)	Dept. of Defence Research and Dev.		
		x)	Dept. of Atomic Energy		
		xi)	CAPART		
		xii)	NIDC		

3.1 **Institutional structure (Urban Water Supply and Sanitation)**

a)	Responsible Ministry	Urban Development	Chief Engineer PHE Dept.

4. **Duration of the current five year plan**

a)	Seventh Five Year Plan	April 1985 to March 1990

5. **Financial Year** 1st April to 31st March

RESEARCH INPUTS FOR USE OF "WATER HARVESTING" IN PROVIDING DRINKING WATER TO RURAL POPULATION

ABSTRACT

Sustainable drinking water supply to problem villages can be provided either through location of subsurface natural source or through collection of rain water and conservation of the surface and ground water which may be otherwise removed from a needy region through natural processes such as drainage and evaporation. Use of different water-harvesting methodologies for supplying drinking water is particularly relevant to areas where source finding is becoming difficult either due to scarcity of the source or due to overexploitation of aquifers. It is also a better alternative in areas having brackish or fluoride or iron rich ground water.

The various aspects of water-harvesting methodologies suitable for different Oroclimatic zones are described in this paper. Four areas requiring R&D support by the Water Technology Mission have been identified. They are :

1. In situ water-harvesting in high rainfall (>1500 mm) hilly areas and areas having ground water of inferior quality.

2. Artificial recharge of hard rock aquifers in low rainfall (500mm to 1000mm) areas.

3. Enhancement of runoff collection through catchment treatment in very low rainfall (<500 mm) areas.

4. Evaporation control through development of chemical films and hydrophobic coating materials.

It is recommended that an optimal number of water-harvesting structures of various types and capacities should be developed within a watershed as a planning unit.

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1. INTRODUCTION

The broad objective of the Water Technology Mission constituted by the Govt. of India is to provide adequate safe drinking water to rural population through the application of all the available scientific and technological inputs from various laboratories and by promoting better water management. The Technology Mission has constituted four Sub-Missions on (1) conservation of water and recharging of aquifers., (2) eradication of Guineaworm (3) control of fluorosis and (4) removal of excess iron.

The methodology for the first Sub-Mission which deals with villages having no sustained source of drinking water, comprises

(a) Exploration of new source and

(b) development of water harvesting structures.

Although the objectives of the Water Technology Mission are limited to provision of drinking water, the problem cannot be treated in isolation. Domestic water supply comprises only a small percent of the irrigation water requirement in the rural area and even partial successes in conservation and economy in the use of water for irrigation may help in achieving year round sustained domestic supply.

In view of the unprecedented increase in ground water exploitation, source finding through exploration is being more and more difficult. It is therefore, necessary that we retain the precipitation in the area where it occurs in order to meet the domestic requirement of the population.

2. WATER HARVESTING

In the context of the Technology Mission on Drinking Water, the term "Water harvesting" connotes collection and storage of rain water and also other activities aimed at harvesting surface water and ground water, prevention of losses through evaporation and seepage, and all other hydrological studies and engineering interventions aimed at conservation and efficient utilisation of the limited water endowment of a physiographic unit such as a watershed or a geomorphic basin.

The various activities and structures covered under Water Harvesting, therefore, are :

1. Construction of permanent/portable water storage structures with accompanying collection systems.

2. Farm ponds, for soil conservation and storage of supplemental water or for recharging the aquifers.

3. Check dams : these are normally constructed for soil conservation but they also effectively serve the objectives of water retention and recharge.

4. Percolation tanks : constructed at appropriate sites selected on geological considerations and designed for the purpose.

5. Reclamation/revitalisation of traditional water harvesting structures such as tanks, pushkaranis and ponds which have deteriorated over the years due to silting and poor maintenance.

6. Artificial recharge of aquifers through injection wells using seasonal surface water surplus.

7. Control of evaporation from surface water bodies and bare soil surfaces.

8. Prevention of seepage losses in appropriate situations.

9. Enhancement of runoff through mechanical and chemical treatment of catchment in low rainfall areas.

10. Subsurface dams across ephemeral streams to arrest loss of ground water through base flow (subsurface flow along the stream bed).

11. Soil and water conservation practices comprising contour and terrace bunding besides trenching.

12. Control of sea water incursion as well as subsurface discharge of fresh water into sea in the case of coastal aquifers.

13. Control of transpiration losses of water through plants without affecting the normal growth through spraying of appropriate chemicals.

14. Adoption of crops and cropping patterns appropriate to the agroclimatic conditions of the region. (eg. at present paddy and sugarcane are cultivated in the drough prone districts of Anantpur of Andhra Pradesh and Kachh of Gujarat respectively which is a absurd situation).

Some of the activities listed above are already being carried out by line departments of the Central Government and the State Governments. These activities need to be reoriented and provided with the perspective of the Water Mission. This point is illustrated through two examples.

1. The soil-conservation and afforestation activities are being carried out all over the country. In the high rainfall hilly regions (eg. the Dang district of Gujarat) the shallow open wells located in valleys became dry in summer months. If afforestation and soil conservation measures are undertaken on priority basis around such a water source then it would result in water retention with delayed recharge, thus improving sustainability of the well.

2. In the very low rainfall areas of Rajasthan, open tanks (Johads) with steps or platforms reducing the floor area with depth are traditionally constructed. These Johads are being constructed at present also, under famine relief or rural employment programme. While the traditional design is necessary for structural stability, it does not take into account the evaporational losses from the surface. Average annual potential evaporation losses in this area are as much as 2.5m which is also the average depth of the Johads. It is thus imperative that roofs on stilts should be an essential part of all such structures.

The present paper deals with only those of the 14 activities listed above which are at present at a stage where Research and Development work and pilot studies are required before the methodology can be demonstrated as effective, economically viable and implementable by the line departments.

Water Harvesting is traditionally practised in arid and semi-arid regions. However, it is equally useful in the high rainfall hilly regions and is a better alternative in areas where ground water quality is affected by salinity, high flouride or high iron content.

3. OROCLIMATIC ZONES AND APPROPRIATE WATER HARVESTING METHODOLOGY

Taking into consideration the rainfall isohytes, the agroclimatic zones formulated by the ICAR and the topographic features, the country can be divided broadly into the following zones from the point of selection of appropriate methodology for water harvesting.

1. High rainfall (>1500 mm) hilly regions comprising broadly Himalayan foot hills, NE region and Western Ghats.

2. High rainfall (>1500 mm) island chains of Andaman, Nicobar and Lakshwadweep. Also coastal deltas of Ganges, Mahanadi, Godavari, Krishna and Cauvery.

3. Plateau region having rainfall between 1000-1500 mm comprising parts of Madhya Pradesh, Bihar, Orissa, West Bengal and Andhra Pradesh.

4. Indo-Gangetic alluvial region in U.P., Bihar and West Bengal (1000 to 1500 mm).

5. Plateau region with low rainfall (500 mm to 1000 mm) comprising Eastern and Northern Maharashtra, parts of Gujarat, Andhra Pradesh, Karnataka, Tamilnadu, Rajasthan, Haryana, Punjab and Western Uttar Pradesh.

6. Arid regions with rainfall less than 500 mm comprising western Rajasthan and Kachcha area of Gujarat.

   Out of these six regions, the plateau region (oroclimatic zone No. 4) and the alluvial region (No. 5) do not have, in general, inadequacy of drinking water source. The problem in these two regions is mainly of quality of the water than of quantity.

4. RESEARCH PROGRAMS IN WATER HARVESTING

The specific R&D efforts required in the remaining zones are described below.

I. High rainfall hilly region

This zone is characterized by heavy seasonal precipitation and runoff. The wells dry up during summer months of March, April and May. Traditional alternative sources are the springs which are also found to be dwindling and drying in summer months. Roof-top collection for use by the family can be practised but this is not a solution for those living in thatched huts and it is also not a source for community supply.

In-situ harvesting through direct collection of rain water in trenches excavated for the purpose can be considered in such a situation. The depth of the average rainfall would vary between 1.5 m to 3.0 m depending upon the location. The trench could be deeper by 0.5 to 1.0 m. The author has participated in an experiment in which four such trenches of the size 8m x 2m x 4m (depth) were constructed on a laterite plateau near Malwan on the West-Coast of India.

In the case of laterite, the angle of repose for the retaining wall can be as much as 90° and the excavated material in brick form can be used elsewhere or can be sold. About 4% of the total area of the country is covered with lateritic soil. In other high rainfall areas, the side walls of such a trench could be sloping with the degree of the slope decided by the stability of the overburden.

In the Malvan experiment, the water was harvested for irrigating mango orchards and the size of the trench was decided on the basis of annual requirement per Hectare. These trenches were subjected to different water proofing treatments. One trench was provided with concrete lining, and Tar was used in the second case. A small size pit (1m x 1m x 1m) was coated with epoxy resin which was found to be effective.

Such trenches can also be constructed in the upper reaches of a hill where the intake area of a spring is located. In such cases, the trenches are obviously not to be lined. They would help in extending the process of recharging the springs beyond the monsoon months, thus increasing the yield and improving the sustainability of the springs.

The following grey areas in the in-situ Water-Harvesting method remain to be studied through a regular R&D project. Also the Malvan experiment needs to be repeated in the Himalayan foot-hills of Northern and Northeastern regions.

(a) Selection of appropriate chemical sealants for water-proofing through multi-trench testing.

(b) Tracing and mapping of the intake area of a spring, monitoring its natural discharge and quantifying the increase in the discharge after construction of trenches.

(c) Cost-benefit assessment in both the cases stated above.

It is suggested that an R&D project on in situ water harvesting, comprising both the aspects of storage, for direct use and for augmentation of springs, should be undertaken in the Cherapunji region of Meghalaya by the Water Technology Mission.

II. Low rainfall Plateau region

The traditional Water-Harvesting practice in this area, mostly covered with hard rocks such as granites and basalts, involves construction of tanks, bunds, pushkarnis and ponds. Most of these traditional constructions do not take into account and consequently do not provide for evaporation losses which can be as high as 1.5 to 2.0 m per year. the total surface area is quite large compare to average depth.

Since the rainfall is inadequate for cultivation of crops like paddy or for multiple cropping, ground water exploitation has increased phenomenally over the years. The water table has shown regional decline and the supply situation had become quite precarious in large tracts during the 1987 drought year.

Artificial recharge of aquifers is the appropriate water-harvesting methodology having general applicability in this zone.

Artificial recharge would :

1. Augment the groundwater reserves.

2. Prevent evaporation losses.

3. Reduce amplitude of torrential discharges in streams.

Although artificial recharge in soft rocks and alluvial terrains is practised world over, artificial recharge in hard rocks is a relatively new areas in which considerable R&D efforts are needed before it can be adopted as a conservation measure by the various State Government.

The currently practised mode of artificial recharge in hard rocks comprises construction of percolation tanks. However, these area meant to recharge only the top unconfined aquifer. The current exploitation trend in hard rocks involves tapping of deeper confined aquifers which can be augmented only through water injection in boreholes.

IIa. Percolation tanks :

The percolation tanks constructed for artificial recharge are not much different from the tanks constructed for minor irriglation. the design does not aim at reducing evaporation losses. Siltation of the tank bed reduces the percolation rate over the years. The efficiency of such tanks in terms of the quantity of water transferred underground is not assessed.

An R&D project in the basaltic and granitic areas, involving following aspects, needs to be undertaken by the Water Technology Mission.

- Use of remote sensing and ground surveys for selecting a tank site in an area having a high permeability.
- Design of the tank to achieve maximum possible storage per unit area in order to directly reduce evaporation losses.
- Experimental trial of newly developed wind-resistant chemical monolayers (details described subsequently) to further reduce evaporation losses.
- Monitoring of evaporation from the tank and seepage through the bunds.
- Inventory of the command area wells and detailed study of their hydrogeology.
- Stable isotope ratio measurement in water samples from the tank and the command area wells to estimate the contribution from the tank to the wells and to assess the extent of the sub-surface command area.
- Calculation of overall efficiency of the tank and cost-benefit ratio.

IIb. Artificial recharge through injection boreholes in hardrocks :

Artificial recharge through injections involves transfer of surface water to aquifers through boreholes drilled for the purpose. the technique requires availability of surface water which is not always assured in the low rainfall region. the author is involved in the following two experimental approaches which use the existing surface storage structures.

(i) Artificial recharge through in-tank wells :

This approach comprised construction of a bore well at a hydrogeologically-geophysically selected site in the percolation tankbed, when it is dry. The well is surrounded by a filter-bed and the entire assembly is so designed that only filtered water enters the well after the assembly is submerged under the tank water for several months.

(ii) Siphon recharge :

A silted up minor irrigation tank was selected and the supernatant water collected in this tank during monsoon was transferred continuously for a long period (6 months) into a bore-hole drilled inside an open well in the command area, by using a siphon.

Both the approaches appear to be promising. However, it is necessary that the Water Technology Mission undertakes an R&D pilot project involving following studies in granites and basalts, before the method can be transferred to line departments :

- Measurement of the flow in the submerged injection well.
- Tracer studies for understanding the pathways of the dispersal of water transferred to the deeper aquifer at a point through injection well.
- Prevention of clogging.
- Improving the permeability of the injection borewell and surrounding aquifer through hydrofracturing.

III. Enhancement of runoff through treatment of the catchment surface.

In the western parts of Rajasthan, traditionally Tankas (Johads) and Nadis are constructed for collection of runoff water which is used for drinking by humans and cattle. In a natural situation, the efficiency of runoff in terms of the fraction of the precipitation depends on factors such as antecedent moisture content of the soil, intensity of the event, total amount of rainfall in the event and the time gap between successive events. It is thus possible that for the same total rainfall, the amount of runoff and consequent collection in the storage structure in two consecutive years can be quite different. Thus, in addition to the low quantum of the total rainfall at a site, the changes in its pattern from year to year also gives rise to uncertainty about adequate storage.

Detailed study of the rainfall pattern of a few stations in Rajasthan shows that the component of rainfall contributed through thunder storms increases as the average annual rainfall decreases. In other words, most of the precipitation is received through a few intensive showers. These intensive events are separated from each other by a few weeks, even during the monsoon months. The antecedent moisture in the hot desert soil is negligible and a large fraction of the rainfall is infiltrated in the soil to shallow depath and is again returned to atmosphere in the subsequent dry period.

An approach towards solving this problem would comprise treatment of surface soil of the catchment area of a tank in order to (a) stabilise it to a depth of a few centimeters and (b) make its surface water-repellent. The runoff efficiency can increase upto 70-80% of the precipitation after such a treatment. The tanka can then get filled in abnormal rainfall years and also irrespective of the rainfall pattern for the year.

Several soil sealing, stabilising and hydrophobic chemicals are known and laboratory experiments for suitablly modifying the soil properties have been performed. However field trials have not been carried out. It is therefore, suggested that the Technology Mission may undertake an R&D project for enhancing runoff at a few sites in the districts of Rajasthan selected for Mission studies (Barmer, Churu and Nagour).

The project shall comprise following salient aspects.

1. Collection of soil samples from catchment areas of existing tanks.

2. Laboratory tests for selection of chemicals specifically suitable for providing stability and hydrophobic properties to these soils.

3. Mechanical treatment of the catchment surface and spraying of the chemical before onset of monsoon.

4. Collection of hydrological data comprising measurement of rainfall and its intensity.

5. Control (blank) experiment with monitoring of rainfall and runoff in a nearby tanka having similar conditions but untreated catchment surface.

The main advantage of this methodology, if found successful, is that it can be practised at any remote location in the desert. Even low rainfall (say 100mm) is adequate for drinking water purpose, if it can be harvested properly.

IV. Evaporation control :

Evaporation control or retardation is required for practically all types of surface storage structures. At present very little attention is paid to this aspect. The annual evaporation loss from surface water even in hill stations is as much as 1.0m and that in desert places is upto 2.5 m.

Evaporation reduction can be effected through two approaches :

1. Design of the storage structure :

   The average depth of the storage structure should be increased to the extent permissible by the local terrain and also by economic considerations.

2. The evaporation rate can be retarded to a considerable extent by spreading a monomolecular layers of fatty alchohols such as Cetyl Alcohol and Stearyl Alcohol. While these chemicals were capable of reducing the evaporation rate by about 25%, it was found that such films could not withstand wind speeds above 15 km/hour and were, therefore, not very successful in field applications.

   Recent work at the National Chemical Laboratory (NCL), Pune has shown that mixed monolayers of Alkoxyethenols can withstand high wind velocity upto 39 km/hour and may, therefore, in general remainstable in field conditions. The reduction of evaporation rate with these compounds is also considerably higher.

3. In coastal areas or on islands, where the near surface ground water is brackish, it becomes imperative that the water-harvesting ponds have shallow depths. The surface area of such ponds is large and the wind velocities are also high. The water surface in such cases needs a more stable cover.

R&D in evaporation control should therefore concentrate on :

(a) Formulation of design guidelines in the case of percolation tanks and other water-harvesting structures for reducing evaporation losses.

(b) Field trials of the Alkoxyethanol films developed by NCL.

(c) Development of polyurethene sheets of appropriate density coated with hydrophobic chemicals.

5. GENERAL REMARKS

The development of water-harvesting structures under the Technology Mission or other subsequent government programs will get considerable fillip if the R&D projects on the following aspects are solicited and funded by the Mission Directorate.

1. In situ Water Harvesting in high rainfall hilly areas.

2. Artificial recharge in hard rocks areas.

3. Chemical treatment of catchment surface in desert areas.

4. Laboratory and field studies for reducing evaporation.

However these studies cannot be made in isolation. They need to be backed by appropriate data base. The various parameters for which the information needs to be collected or generated are :

(a) Rainfall, runoff and evaporation.

(b) Natural recharge of the aquifers.

(c) Acqufer geometries and hydrological properties.

(d) Pedology, geology, structural controls.

(e) Chemical quality of water.

(f) Current land and water use practises.

It is also desirable that this information is collected for the watershed in which the field-trials for the particular research project on Water Harvesting is to be carried out. The symbolic effect of implementation of various water-harvesting structures and methodologies recapitulated in this paper should be such that water in any phase or form would be permitted to leave the watershed only after the domestic and irrigational requirements of the population are stored in farm-ponds, check dams, percolation tanks, minor irrigation tanks, aquifers etc.

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STRUCTURAL ENGINEERING RESEARCH CENTRE, GHAZIABAD

RESEARCH & DEVELOPMENT PROJECT ON RAIN WATER HARVESTING

PROJECT

Development of designs & construction Techniques for mini check dams, Medium capacity Ferrocement tanks (upto 50000 litres capacity) for storing drinking water in underground, partly underground, above ground conditions.

INTRODUCTION

In the areas having enough rain fall but with problem of non-availability of drinking water, the water shed management for diverting and storage of rain water surface run-off (when it is available) are very important for solving the problem of drinking water to population living in these areas. In the water shed management, the flow of the rain water run off can be diverted to areas/points of water storage in tanks/lakes/reservoirs etc. for use during dry season. Small height check dams are constructed for managing the flow of water in the desired direction. Presently, these check dams are constructed using earth/stone/brick masonary. Masonary check dams are expensive and slow in execution. If prefabricated RCC/Ferrocement units are used for such schemes, the construction time can be reduced considerably. These units will also be useful for recharging the ground water strata in an area by water stagnation method and also for construction of mini dams over natural shallow streams in hill areas.

OBJECTIVES

1. Development of designs and construction techniques for mini check dams which will be useful for diverting flow of rain water run-off to storage areas and for recharging of ground water strata. Precast RCC/Ferrocement check dams are being developed for heights upto 1.5 Meter.

2. Development of technqiues and methods for making existing masonary check dams leakproof by easy to carry out lining methods.

3. Development of design and construction techniques for Medium capacity/ underground and ground surface tanks upto 50000 litre capacity for use in Drinking Water Mission Projects.

4. Training of field Engineers and artisans in techniques developed.

5. Development of Techniques for lining of underground dug tanks for storing water in soils like laterite.

ACHIEVEMENTS

To fulfill the objectives of the Project, following work was undertaken so far.

1. **Ferrocement mini checkdams for harvesting of rain**
Water run off from surfaces, shallow hill streams and for recharging aquifers or for divertion structures :-

   (i) Design of Mini Ferrocement checkdams for the construction of Mini Checkdams of heights upto 1.5 M (clear) have been completed.

   (ii) Technology for precasting and jointing of Ferrocement mini checkdams for clear height upto 1.2 M, has been developed.

   (iii) Several checkdam units have been cast and jointed together for studying problems at site.

   (iv) A 7 meter long prototype mini checkdam has been constructed and erected for testing and studying the problems in casting, erection, transportation and assembling of these checkdams. The prototype has been tested by filling water on one side of the structure and observations have been made for leakage for 3 months. This prototype has been found water tight. The work of other sizes is going on.

   (v) A new type of Precast F.C. element easily jointable at site has been developed for reducing weight, transportation cost of Mini Ferrocement Checkdams.

2. **Casting techniques for Ferrocement filter**

Low cost techniques has been developed for casting of F.C. filters for use in rain water collection schemes. The technique has been successfully demonstrated in Manipur, Meghalaya, Madhya Pradesh Nagaland and Tripura.

The SERC technique for filters, has already been adopted by PHED Meghalaya for 600 rain water harvesting structures under construction in Nongstoin Area of Meghalaya and for a few RWHS in Tripura, Nagaland and Manipur.

3. **Ferrocement Water Storage Tanks**

Few years ago, S.E.R.C. (G) developed and released Technology for F.C. Water tanks, upto 20000 Litre capacities. S.E.R.C. Technique involve using of precast segments for wall, roof and base. This technology has been demonstrated during training courses at Roorkee, Ghaziabad, Bhopal (M.P.), Maramkullen (Manipur), Shillong (Meghalaya), Dimapur (Nagaland) and Agartalla (Tripura).

In the technologies developed at SERC, the tanks can be fabricated in pieces which can be joined at site easily or the entire tank can also be cast at site itself. Designs for medium capacity tanks for capacities upto 50000 litres have been developed using segmental construction technique. A prototype unit for 65000 litre will be constructed and tested.

4. **Direct Ferrocement lining over stiff soils**

Techniques for construction or underground water tanks by direct lining over stiff soils. using Ferrocement as construction material, have been developed for storing rain water. The technique has been tested at SERC (G) and has been found to be satisfactory. A technical note has been prepared for Lining of water tanks dug in Laterite Soils in PUNE area of Maharashtra.

5. **Underground F.C. barriers for stopping underground water flows**

The work of development of technique for use of Ferrocement underground lining barriers for stopping underground water movement has been taken up on a suggestion from Central Ground Water Board.

6. **Preparation** of Manuals on Rain Water Harvesting & construction Techniques for F.C. Tanks are in final Stage.

FUTURE PLAN

Following work has been planned to be carried out.

(i) Ferrocement lining over stiff soils for underground water tanks to be tested and details for the technique to be finalised.

(ii) Development of technique for use of underground ferrocement barriers for stopping underground water movement (to be continued).

(iii) F.C. Water tanks of capacities upto 50000 liter have been designed and moulds for wall segments have been designed (perfecting casting technique continued).

(iv) Manuals on Rain Water harvesting technologies developed by SERC will be published.

TECHNOLOGY INPUTS

FOR

WATER HARVESTING SYSTEMS

RAIN WATER HARVESTING IN MEGHALAYA*

INTRODUCTION

Rain water as a source of water supply to meet the domestic use is not a new concept. In many parts of the world, rain water continues to be the only source of domestic water supply. However only recently, harnessing of rain water as a water source for domestic water supply has been taken up in right earnest on a scientific basis.

Rain water may be harvested in remote hilly areas, having rainfall of considerable intensity, spread over the larger part of the year. This is an ideal solution to water problem where there is no ground water is available and surface sources are very far. Ideally suited from the economical point of view, where the houses are scattered over a wide area and are located at different elevations. It is a simple low cost technology requiring no maintenance cost.

There are various methods of rain water collection available, but in this paper Rain water harvesting from "Roof top collection" as introduced in Meghalaya is dealt with. Rain water is bacteriologically pure, free from organic matter and soft in nature. It is only during collection or during storage or during handling, there is a possibility of contamination. Therefore, utmost care has to be taken during collection, storage and handling to keep the water free from contamination. People should be educated that the quality is important rather than the quantity.

Rain water harvesting scheme for rural water supply was introduced in the West Khasi Hills district of Meghalaya under the auspices of the Technology Mission. The drawings and designs were supplied by the Technology Mission and on basis of the same, estimates were prepared.

ESTIMATION OF YIELD

The maximum yield possible from a rain water catchment system is directly proportional to the catchment surface area, its runoff co-efficient and the amount of rainfall. Field measurements

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indicate that a portion of rainfall serves to wet the catchment, a portion evaporates and a portion is wasted as 'foul flush' in case of roof catchment. The portion of the rainfall actually harvested ranges from 30% for pervious flat ground catchment, over 90% for covered sloping ground catchment. Thus run off co-efficient factor 'f' ranges between 0.3 to 0.9 as shown in table-1 assuming there is an adequate storage volume to accumulate any surplus of rainfall over consumption.

Table - 1

Type of catchment	= Harvestable rainfall / Total rainfall
Uncovered catchment surface	
Flat	0.3
Sloping 0-5%	0.4
Sloping 0-10%	0.5
Sloping 10%	0.5
Covered catchment	
Roof tiles	0.8 - 0.9
C.I. sheets	0.7 - 0.9
Brick pavement	0.7 - 0.8
Compacted soil	0.4 - 0.5

The yeld 'Y' of a catchment area 'A' m^2 receiving rainfall 'R' mm in a month is given by

$$Y = \frac{f \times A \times R}{1000} \ m^3/\text{month}$$

If 'p' number of people is to be served with drinking water from a rain water system at a rate of 'q' litres per day, the amount of water 'O' to be supplied per month will be

$$Q = \frac{P \times 30 \times q}{1000} \ m^3/\text{month}$$

STORAGE CAPACITY

The total storage capacity required depends on

- Number of people to be served
- Daily per capita requirement in litres/day
- Number of consecutive days without rainfall (usually 90 to 120 days)
- Amount of rainfall and its duration
- Size of catchment area
- Losses of water due to evaporation and leakage

On the basis of rainfall and critical dry period (90 to 120 days normally), the minimum storage volume can be computed from :

$$V = \frac{P \times q \times D}{1000} \ m^3$$

Where P = number of persons
q = daily consumption rate in litres per day
D = number of critical dry days.

Essential components of Roof top collection Rain Water Harvesting Scheme.

a. Roof catchment

b. Gutters for collection of roof water

c. Down pipe to convey rain water from gutter to storage tank

d. 'Foul Flush' system to divert the contaminated run off from roof

e. Filter

f. Storage tank above or under ground

g. Water withdrawal arrangement

h. Disinfection arrangement

Roof : Roofing may be either G.I., Aluminium or A.C. sheets or even tiles. Although thatch roof is not very suitable, the same can also be used by covering with plastic or polythene sheet.

Gutter : Gutter of plain G.I. sheet or local materials such as wood, bamboo etc. may be used. All gutters should have adequate slope for free flow of water.

Down pipe : The down pipe is used for feeding the water from the gutter to the storage tank. This pipe should be at least 100 mm dia provided with a 20 mesh wire screen at the inlet to prevent dry leaves and other debries from clogging it.

Foul Flush : During the period of no rain, dust, bird droppings etc. accumulate on the roof. These are washed off with the first rains and enter the storage tank to contaminate the water. This can be prevented by two methods :

a. Simple diversation of foul water

b. Installation of foul flush system

Under method (a), the down pipe is moved away from the inlet of the storage tank during the rains untill clean water flows. Under method (b) storage provision for initial rain is kept in a pipe or bore. These are cleaned off after each heavy rain.

Filter : A filter is provided between down pipe and storage tank after foul flush. This filter may be of Brick, R.C.C. or Ferrocement. The filter is cleaned every three months.

Storage Tank/Cistern : This is the most important and costliest component of the scheme. The rain water collected from the roof catchment is stored in this tank. The tank or cistern may be of Brick, Stone, R.C.C. or Ferrocement. The tank is provided with

- a man hole of 0.50 m x 0.50 m size with cover
- Vent pipe/over flow pipe (with screen) of 100 mm dia
- drain pipe (100 mm dia) at bottom.

Choice of tank depends on locally available materials and space available. When the tank is constructed underground at least 30 cm of the tank should remain above ground.

WATER WITHDRAWAL ARRANGEMENT :

If the tanks are constructed underground because of the low height of the houses in the rural areas, a shallow hand pump is required to be provided for withdrawal of water, otherwise a burib-cock will suffice.

DISINFECTION ARRANGEMENT

Before the tank is put to use, it should be thoroughly cleaned and disinfected with chlorine solution.

DESIGN CONSIDERATIONS

In the design of the system, the main criteria is the most economical combination of the storage tank, volume, systematic analysis of rainfall records and construction costs. Thus the main design factors which need careful considerations are

1. Number of people to be served
2. Water demand
3. Area of catchment
4. Rainfall
5. Evaporation and other losses
6. Filter

Number of people : number of people in each house hold.

Water demand : 10 lpcd

Roof catchment : effective roof areas is the ground area covered by the roof.

Filter : Filter media may be sand, coconut fibres supported on gravels

1st :	Gravel 12 mm size	4 cm deep
2nd :	Fibre	3 cm deep
3rd :	Coarse sand	8 cm deep
4th :	Fibre	3 cm deep
5th :	Stone boulders ...	8 cm deep

Details are shown in drawing.

Rainfall : For designing rain water harvesting system, monthly rainfall provides the best basis. The average monthly rainfall distribution averaged out of the 10 years record, reflects the seasonal pattern quite clearly.

On the basis of rainfall data, a schematisation of annual rainfall pattern may be made and from this design, dry period can be arrived at.

COST OF CONSTRUCTION

In the West Khasi Hills district of Meghalaya, the rain water harvesting schemes have been designed at 10 lpcd for 90 days critical dry period. An average cost for a house hold of 8 persons are furnished below :

1.	Cost of tank	Rs. 7000.00
2.	Cost of gutter, down flow pipe polythene sheet cover, clamp including carriage and labour for fitting	Rs. 1500.00
3.	Cost of hand pump including carriage and fitting	Rs. 321.00
4.	Ferro cement filter	Rs. 695.00
		Rs. 9516.00

Thus the per capita cost works out to Rs. 1189.50. This is considered quite economical as the piped water supply scheme costs Rs. 2000.00 to Rs. 5000.00 per capita in most of the villages.

MOTIVATION

As the Rain Water Harvesting is new to this area, considerable difficulty was faced to motivate the people to accept the programme. For this purpose, awareness campaigns were launched in the form of melas where posters and models of Rain Water Harvesting scheme were exhibited. Initially the response was poor, but after observing the benefits in the neighbouring villages, more and more people have come forward to accept the scheme. It is however observed that sometimes the people are not careful in allowing the foul water to drain out and some times even the manhole covers are kept open, which leads to contamination of the water. Further there is a tendency to withdraw excessive water, which might result in shortage of water during the dry period. The people are constantly reminded about rejecting the water from the first shower after an interval and keep the man holes covered properly. While there is no shortage of water during the rainy season, the water collected towards the end of the rainy season has to be used sparingly which the people have been made aware of.

By and large the people are quite happy with the scheme as even in the rainy season, they had to go very far to fetch water. Now they have got unlimited water supply in the houses during the rainy season. Demands for Rain water harvesting schemes have also been received from some villages where piped water supply schemes were provided earlier as there is no disruption of supply in the Rain water harvesting schemes.

LIMITATIONS

1. Rain water harvesting schemes are not suitable for villages which are likely to shift.

2. Rain water itself is dependant on rainfall in the area which at times can be erratic.

3. Although the rain water can meet all the demands of the people during the rainy season, it has to be used sparingly during the dry period.

RAIN WATER HARVESTING IN MIZORAM*

The usual methods, traditionally employed, for water supply in Mizoram for consumption are manual fetching from spring sources and collection of rain water from the roof tops. The people of Mizoram prefer rain water to other sources mainly due to the scarcity of water and small yield of the spring sources, which are located at far off distances from the villages.

RAIN WATER HARVESTING

The spring water sources are usually located below the villages and water had to be carried uphill, and are also far from the villages. The yield of the sources are very much inadequate to feed the populaltion in dry season. They generally dries up during the dry season. Maybe due to the young geological formation, the soil had very low capacity of retaining water. As fetching of water involves walking long distances and waiting for hours to get a bucketfull of water, it is not economical due to wastage of precious mandays. Due to the reasons stated above, people have been using rain water, collected from roof tops, for their everyday need. This is possible as the rainfall in Mizoram is very high, i.e. 250 cm per annum and last for five months in a year. The quality is also found to be fit for human consumption. Simple treatement by chlorination with Bleaching Powder is enough. Thus, rain water harvesting is not a new thing in Mizoram, as it had been in practice since long.

DESIGN PARAMETERS

The design parameters for Rain Water Harvesting Scheme, to meet the barest minimum water demand adopted in Mizoram are as follows :

(A) **Rate of Supply**

(i) For drinking purpose only = 3 lpcd

(ii) For drinking and cooking = 10 lpcd

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(B) **Duration**

Mizoram has very good rainfall, about 250 cm a year, and for design purpose 120 days a year is taken as period without rain.

(C) **Materials**

Materials most commonly used for the tanks are Plain or galvanised G.I. Sheets. Ferro cement tanks are also tried but this is not yet practicable in large quantity due to difficulty in procurring cement and non-availability of good sand.

(D) **Per Capita Cost**

Per capita cost for 15000 litres capacity G.C.I. Tank as now used in Mizoram is as below:

(i) Rs. 235.00 per capita based on the supply rate of 31 lpcd.

(ii) Rs. 1000.00 per capita for supply rate of 101 lpcd.

COMPARISION

The cost per capita for gravity feed scheme in Mizoram, using G.I. Pipes ranges from Rs. 1,000.00 to Rs. 3,000.00. Whereas for Rain Water Harvesting Schemes, the cost is Rs. 1000.00 per capita. Thus, Rain Water Harvesting Schemes compare favourably with Gravity Feed Schemes, as far as Mizoram is concerned. But gravity feed schemes give more water.

CONCLUSION

Although the per capita cost of Rain Water harvesting Scheme is less than that of piped water supply system in Mizoram, yet it cannot be considered as an alternative or cost effective, rather it can be considered a good system for supplementing piped water supply system. This is due to the reason stated below :

(i) Rainfall is not reliable and varies time to time.

(ii) Continuous supply of water is not possible throughout the year due to irregular rainfall.

(iii) To store enough water required for all purposes it will be necessary to construct tanks of very large sizes. The cost of large tanks will be also high and will not be economical.

In plain areas, rain water may be polluted due to Air Pollution, unlike Mizoram, where there is practically no problem of air pollution, and rainwater will require high degree of treatment which will be very costly. Moreover, in plain areas, good and dependable surface and ground water sources are available, which may be tapped at a cheaper rate in comparision to harvesting of rain water.

ARTIFICIAL RECHARGE OF GROUND WATER*

P.N. PHADTARE*

1. INTRODUCTION

Ground water, the elixir of organic life, is unlike other minerals found in the crust of the earth, is a replenishable resource. Rainfall is the source of annual ground water replenishment and the movement of rainwater down to the ground water reservoir takes place by several ways, such as, direct infiltration through surface soils and rocks, vertical percolation from surface water bodies and sub-surface movement through the permeable media. In the tropical countrys like India, the recharge through rainfall takes place only during the short period of monsoon but due to slow sub-surface movement of ground water, it is available for use throughout the year, in almost all the areas except the highly permeable cavernous limestones, bouldery formations, areas of very high topographic gradients and areas of excessive ground water draft. Excessive draft is observed in three types of areas i) Thickly populated and industrial areas ii) Highly progressive agricultural areas and iii) Thickly forested areas which discharge ground water due to evapotranspiration.

Where tne ground water resources are inadequate that is where the ground water draft, either due to extraction by wells or as sub-surface run-off, exceeds annual replenishment, additional recharge by artificial methods is necessary. Overexploitation of ground water has become a common phenomenon in most parts of the country on account increasing population and heavy demands for irrigation and industrial uses. Artificial recharge is an important aspect of ground water management as it provides storage space free of cost, avoids evaporation lossess and allows use of stored water during/dry period. Unlike surface reservoirs, the underground reservoirs can be used for indefinite period, if properly operated. They are also free from major adverse effects of natural catastrophes. Artificial recharge is also adopted where there is need for improving the quality of ground water or where there is possibility of ingression of inferior quality of water from adjoining areas.

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2. ARTIFICIAL RECHARGE METHODS

Artificial recharge is achieved by three methods, namely, the speading method, induced recharge method and injection method. A suitable method is selected on the basis of

(1) Hydrogeological conditions

(2) Quality of source water

(3) Proposed use of recharged water

	Conditions	Artificial Recharge Method
a)	Highly permeable surface formations	Spreading method
b)	Shallow aquifers	Spreading method
c)	Source water of inferior quality	Spreading method
d)	Deep aquifers with permeable or semi-permeable overburden	Spreading method
e)	Aquifers with limited storage capacity	Induced recharge method
f)	Deep aquifers with impervious overburden	Injection method
g)	Source water of very good quality	Injection method and/or spreading

2.1 Pre-requistis for artificial recharge

Artificial recharge of ground water becomes essential where shortage of water, either for irrigation or domestic purpose or for industrial purpose, is felt. The excessive demands in such areas are normally met with by drawing water from ground water reservoirs which in turn causes over exploitation. The over exploitation creates space for storage of artificially recharged water. However, unless excess surface water and aquifers of suitable nature are available artificial recharge schemes cannot be implemented. Over exploitation of grund water causes salinity ingress in the coastal areas. In certain areas the ground water has inherent salinity such as areas with marine sedimentary deposits. Ground water salinity is also a problem in areas with semi-arid to arid climate where excessive evaporation causes precipitation of salts from surface waters or areas with interdunal drainage where there is no possibility of flushing of the salts. Artificial recharge together with other water management practices are essential in such areas for improving quality of ground water. Compatibility of the source water and the ground water from the aquifer to be recharged is another important pre-requisit as the chemical precipitation and bacterial growth, caused by the inter-reaction of waters of two different types, causes clogging and reduces rate of recharge.

The aquifer suitability depends mainly upon the storage coefficient, availability of storage space and permeability. Very high permeability results in loss of recharged water due to sub-surface run-off where as low permeability reduces recharge rate. In order to have good recharge rate and to retain the water recharged for a sufficient period to allow its usage during lean period, moderate permeabilities are needed. Older alluvium, burried channels, alluvial fans, duen sands, glacial outwash, are some of the unconsolidated formations which are favourable for artificial recharge practices. As regards hard rocks, fractured, weathered and cavernous rocks are capable of allowing higher intake of water.

Technical feasibility of artificial recharge scheme depends upon storage capability, intake capacity, retention capacity of the aquifers and quality of source water, where as economic viability depends upon the cost of articial recharge structures, the cost of transport of source water and the cost of maintenance and operation. However, the limits of costs vary with the proposed use of the recharged water, such as irrigation, domestic or industrial use. In artificial recharge schemes, the cost escalation is attributed mainly to source water treatment and clogging of structures and subsequent cleaning.

2.2 Artificial Recharge Methods

(i) **Spreading Method** : Artificial recharge by spreading method comprises increase in the surface area of infiltration, thereby allowing more surface for infiltrating waters. It is effected by channel spreading, spreading channels and recharge basins/ponds/pits. Channel spreading comprises bunding of existing stream or river channels either by bunds (check dams) across the channels or by constructing small "L" shaped levies within the channels. Spreading channels comprise unlined channels of gentle gradient which either hold the water or allow the movement of water at very gentle velocity in order to effect maximum infiltration. Recharge basins/ponds/pits help in collecting the surface run off from storm drainages and allowing their collection at places where it can effectively infiltrate into the the sub-surface ground water reservoirs. The levies, bunds, ponds, recharge basins, etc. which accumulate and keep the water stagnant for a longer period, allow more time for infiltration of water, thereby preventing losses due to run-off.

Artificial recharge by spreading has the disadvantages of loss of surface waters by evaporation and decrease in infiltrating capacity of spreading structures by deposition of silt from the source water, deposition of dust from the atmosphere and growth of vegetation on the infiltration surfaces. However, it has following important advantages over the injection method: The infiltration is almost like natural rainfall infiltration and extreme purity of infiltrating water is not needed. Normal storm run-off or primarily treated drainage waters (removal of harmful chemical constituents and supended materials) can be utilised for artificial recharge. Cleaning of the infiltration surface once in a while is an easy process as it involves only scrapping of the surface.

Spreading methods are useful only for recharge to unconfined aquifers. The meagre downward leakage through the aquitards and slow sub-surface lateral movement of the ground water, make it uneconomical to artificially recharge the confined or semi-confined aquifers either by downward infiltration or lateral infiltration through the recharge zone. spreading method which involves stagnation of water, sometimes creates environmental problems. It is, therefore, necessary to adjust supply of water to these structures in such way that large pools of stagnated water are not produced. This is however difficult as most of the artificial recharge experiments are based on collection of storm runoff. The recharge rates also need to be controlled as higher ground water mounds reduce the infiltration rate. The best way is, therefore, to store water underground with the help of sub-surface dykes, so that not only the excess water flows out but it flushes the accumulated silt also. The sub-surface structures are more immune to natural catastrophes. Evaporation losses are also minimum as no water is stored above the surface.

(ii) **Induced Recharge Method** : The natural conditions like hydraulic gradient and vertical head are changed to allow rapid movement of infiltrated waters and to allow more space for storage, respectively. This situation has not arisen in our country so far but it was under active consideration whether such induced recharge can be experimented along banks of

Ganges to direct flood waters underground, thereby effecting flood control measures. However conditions similar to these are getting created in more areas all over India on acount of overexploitation of ground water. In certain heavy rainfall areas where excess rainfall results only in excess surface run-off on accunt of limited storage capacity of aquifers (especially hard rock areas), the overexploitation has helped in higher recharge, that is, though the pre-monsoon levels show progressive declines, the post monsoon levels are always attained. This suggests that overexploitation should be permitted in such areas.

(iii) **Injection Method** : Water is fed directly into the depleted aquifers by providing a conduit access, such as tubewell or shaft or connector wells. Recharge by injection is the only method for artificial recharge of confined aquifers or deep seated aquifers with poorly permeable overburden. The recharge is instantaneous and there are no transit losses and evaporation lossess. Injection method is also very effective in case of highly fractured hard rocks and karstic limestones but very high permeabilities are harmful as they do not allow the water to be retained for a longer period to make its use during dry season. However, requirement of extreme purity of the source water as well as compatibility of source water and water from the aquifer to be injected, are the precautions necessary, otherwise frequent clogging of injection structures, by bacterial growth, chemical precipitation or deposition of silt, results in heavy expenditure on well cleaning. As pumping wells are self cleaning, dual purpose injection wells that is injection cum pumping wells are more efficient. Connector injection well where saturated shallow aquifer and overexploited confined aquifers are tapped in a single well, allows free fall of water from shallow aquifer into the deeper aquifer, thereby reducing cost of injection. Injection method is also used as a "Pressure Barrier Technique" to arrest or reverse saline water ingression.

3. CASE HISTORIES

Technological developments in the pumping method and well construction have resulted in large scale exploitation of ground water. In many countries, which have to face the vagaries of monsoon, dependability on ground water has increased tremendously. In arid or semi-arid regions, availability of surface water is either lacking or is inadequate and storage of surface water is also uneconomical on account of high evaporation losses. Proper storage and management of available ground water resources therefore is very essential in such sources of replenishment of the ground water reservoirs in the arid and the semi-arid regions because the intensity of normal rainfall is grossely inadequate to produce any moisture surplus under normal infiltration conditions. Although artificial ground water recharge methods have been familiar in the developed nations over the past several decades, their importance was felt in the developing nations like India, only during past two or three decades. Methods like nala bunding, percolation tanks, trenching along hill slopes and around the hills, etc., are being practised in many parts of the country but full advantage of such projects could not be obtained for want of scientific orientation of the programmes. A thorough and detailed knowledge of the geological, hydrological and morphological feautres of the area are necessary for selecting sites for recharge structures.

The Central Ground water Board (CGWB) tried to develop methodologies by including artificial recharge experiments as a component in each of its several ground water resources evaluation and exploration projects during past two decades. During 1980-85, the CGWB implemented a full scale Artificial Recharge Project with the assistance of the United Nations Developments Programme and established technical feasibility and economic viability of various artifical recharge methods in the semi-arid and drought affected areas. The findings of these various experiments are summarised below.

i) Studies on artificial recharge through percolation tanks in the Sina and the Man river basins, Maharashtra.

Both the Sina and the Man basins comprise mainly basaltic flows with narrow and shallow alluvial patches. Studies were carried out on seven percolation tanks, to find out their effectiveness and suggest method for improving their utility. The average recharge was 50% of the capacity of the tank, provided the tank bottom was renovated by scrapping the surface, every year before monsoon and the location was selected in such a way that the reservoir area covered vesicular of fractured basalts. Nala (stream) bunding, where the entire storage of surface water was restricted to the course of the Nala, was found to be more effective and economical as the surface exposed to evaporation was on an average 10% of that normal percolation tank. The rate of infiltration varied from 50 to 70% of the capacity.

A connector well tapping phreatic alluvial aquifer of 6 metres thickness and deeper confined basaltic aquifer (63 metres depth), allowed free flow under gravity from phreatic aquifer to the confined aquifer, @ 0.19 MCM per year. The water level in the phreatic aquifer, which was saturated on account of nearness to a small surface reservoir, was 3 metres below ground level (bgl) where as the piezometric level in confined aquifer was 30 m. bgl. It was found out that, the above recharge effected at a cost of Rs. 30,000/- (cost of bore hole) was very less compared to the cost of percolation tank needed for similar recharge (Rs. 4,00,000).

ii) Studies on artificial recharge through percolation tanks and sub-surface dykes in the Noyil Ponani and Vattamalai river basins, Tamil Nadu & Kerala.

Nine percolation tanks were selected in the semi-arid regions of above river basins and data on evaporation, change in storage surface run-off and water spread were collected. It was observed that the rate of percolation was as high as 163 mm/day at the beginning of the rainy season but reduced to hardly 15 mm/day after few months. The reduction in infiltration rate was mainly due to accumulation of silt at the bottom. Periodic desilting was therefore found to be essential.

Sub-surface dykes of 1 to 4 metres height were found effective in augmenting the ground water resources, particularly in the hard rock areas underlain by fractured aquifers.

iii) Artificial recharge studies in the Ghaggar river basins, Northwestern Region.

Artificial recharge experiments through injection well were carried out, using canal waters. The injection rate was 43.8 litres per second (lps) at injection pressure of 1 atmosphere (atm). The pressure increased to 2 atm after 5 hours but remained constant thereafter. However, recharge under gravity was found to be 5.1 lps. The recharge rate also showed gradual reduction to 3.5 lps after few days.

On the basis of repeated tests, it was concluded that the rechatge rate obtainable with injection under pressure is about 10 times greater than the rate obtainable by gravity flow. The increase in pressure during injection was found to be due to clogging. In order to avoid clogging of well, control on quality of source water was recommended. Periodic cleaning of well was suggested whenever the pressure increased beyond 6 atm or showed tendency towards sudden rise.

Studies were also conducted to find out possibilities of induced recharge from the Ghaggar river. Based on the above studies, construction of well-field, not less than 100 m from the river, with spacing of 200 m was suggested. In order to increase the effectiveness of well field so proposed, periodic scrapping of the clay film and clogged upper part of the flood plain aquifer was suggested.

iv) Pilot Project for Artificial Recharge, Gujarat.

Two areas were selected in Gujarat to study, experiment and conduct artificial recharge schemes. In the Central Mehsana area of North Gujarat, where large scale overexplotiation of ground water has resulted inheavey declines during past three decades, artificial recharge was carried out by injection wells, connector wells, and by infiltration channels and ponds. Surplus ground water from the flood plain aquifers of the major rivers in Mehsana area and the tail-end releases from the Dharoi canal system were utilised. In the coastal areas of Saurashtra, Gujarat, where overexploitation of ground water has resulted in salinity ingress, artificial recharge experiments were carried out with the help of injection wells and recharge basins. Storm run-off and tail-end releases from the canal system of Hiran Irrigation Project were used for these experiments in the coastal area. In addition to this, in the coastal area, detailed observations were made at the existing Tidal Regulators and Check Dams to study their effectiveness. Injection of water from the phreatic aquifers into the deeper overexploited aquifers was found feasible in the entire Central Mehsana area. The spreading methods like spreading channels, recharge pits and ponds were found to be economically more viable than the injection method. As regards injection method, connector wells, when used as dual purpose wells were found to be more economical as recharge under gravity reduced the cost of recharging and periodic pumping avoided clogging of wells. In the coastal Saurashtra area, where the aquifers are highly cavernous, rapid underflow of recharged water to the sea does not make the artificial recharge as a viable proposal. However, the tidal regulators were found to be very useful in creating barriers of freshwater along the creeks and coastal depressions. These barriers prevent the sea water ingression very effectively.

The cost of recharge scheme depends mainly on treatment of source water, transportation of source water and stability of recharge structure. In the above experiments, all these factors were critically studied and simple methodologies were tried to overcome these problems, such as (1) Providing higher slopes for sides of spreading structures to avoid silt accumulation (2) Providing gravel pack in recharge pits to avoid caving of sides and to prevent deposition of silt during dust storm (3) Passage of source water through gravel-sand channel for desilting (4) Provision of desilting pits (5) proper gravel pack and thorough well development in the phreatic zone of injection well to allow silt free water to enter deeper aquifers.

v) During the course of Technology Mission work in Jamnagar District of Gujarat it was found that basaltic dykes cutting across streams create good sub-surface stroage.

4. ECONOMICS OF ARTIFICIAL RECHARGE SCHEMES

The Table No. 1 shows the salient features of the economics of various artificial recharge methods.

Table 1
Economics of Artificial Recharge Structures (costs, as on 1/1988)

Artificial Recharge Structure	Initial Cost of structure per 1000 Lit/year recharge Rs.	Operational cost per 1000 Lit. of recharged water Rs.
i) Injection well (Alluvial area)	2400/-	0.700
ii) Injection well (Hard rock)	150/-	0.150
iii) Spreading channel (Alluvial area)	220/-	0.065
iv) Recharge pit (Alluvial area)	225/-	0.070
v) Recharge pond or percolation pond (Alluvial area)	45/-	0.045
vi) Percolation tank (Hard rock area)	37/-	0.036
vii) Vasant Bandhava or check dam	9/-	0.022
viii) Tidal regulator	300/-	0.500

The cost of construction and cost of operation of the recharge structures, except in case of injection well in alluvial area and tidal regulators are reasonable compared to costs of such experiments in other countries. However, considering the requirement of water for irrigation purposes, which is on an average, 5000 M^3/hectare, the additional cost of cultivation on account of irrigation by recharged water works out from Rs. 125/- to Rs. 550/- per crop per hectare, which is quite high. In case of domestic water supply, however, the cost works out to Rs. 0.75 to Rs. 5/- per head per year which is reasonable, especially in areas where there is shortage of water. The cost and initial investment is many times less than that required for supply through tankers which is being adopted in case of shortage of water. However, these works when taken up under scarcity or relief works, where expenditure on labour component is a liability of the State Government, the real investmen which is required is for the material component. The structure thus becomes economically viable. Many such schemes can be taken up under scarcity work, if planned in advance, because drought relief works are needed almost every 5 to 7 years, which is the normal drought frequency in the country.

5. SELECTION OF SITES AND DESIGNS FOR ARTIFICIAL RECHARGE STRUCTURES

i) Injection or Connector Wells : The selection of sites for these structures depends upon the configuration of the confined aquifers, hydraulic gradient and location of source of excess surface water. It is always better to construct it closer to source to save cost of transportation of water to be used for recharge. However, the slow sub-surface movement of ground water does not allow the recharge to be carried out at a distance far off from the source of exploitation. The designs of injection wells and connector wells are not much different from those of the normal tubewells and depending upon the aquifer characteristics, slot sizes, casing sizes and gravel packings are to be selected. These wells are required only for recharging deep confined aquifers. There is no need for recharging shallow semi-confined aquifers between depth range of 40 to 100 metres by injection method as the recharge to shallow un-confined aquifers by spreading method takes care of recharge to such aquifers by vertical leakage through leaky aquitards.

ii) Artificial recharge by spreading methods however needs elaborate filed studies for selection of site and selection of the type of structure :

a) **Channel spreading :** This comprises changing of pattern of the surface flow in the river channel with the help of "L" shapped levies (sand bunds) so that instead of flowing rapidly downstream, the river water becomes sluggish, adopts longer route and thus provides more time for its infiltration. In our country where the rivers are ephemeral and prone to flash floods due to restricted period of monsoon, this method is not helpful.

b) **Spreading channels :** They comprise passage of water through unlined canals which in turn recharge the ground water reservoir. The spreading channels are similar to unlined canals with side slopes of 1 in 1 and very gentle floor gradient. The gentle floor gradient allows very gentle movement of water thereby allowing more time for infiltration and also reducing erosional action of water. Moderately high slopes of sides make these structrues more stable and prevent wind blow silt from depositing on sides. The channel however needs periodic scrapping of floor to remove accumulated silt and weeds at the bottom. These structures are costly and need very high order of maintenance and supervision. They are not suitable for augmenting drinking water supply where requirement of recharge is limited and high costs are prohibitive. these channels are very effective as irrigation cum spreading channels and are very gainfally used in certain river basins - e.g. the flood water spreading channels of the Mahanadi basin in Chattisgarh region of Madhya Pradesh, the Ganga canals, etc. Instead of this, contour trenching which is a spreading channel system of limited extent, is more useful as it not only reduces surface run-off but helps in preventing soil erosion. These are ideally suited for valley slopes in hilly areas where surface run-off is very high. Planting of trees, along contour bunds or trenches, further helps in reducing surface run-off and soil erosion.

c) **Recharge pond :** It has been observed that the recharge ponds, percolation tanks, check dams or sub-surface dykes, which come under this category, create a ground water mound down to the full thickness of the aquifer. This gorund water mound spreads around as a dome upto 100 to 1000 metres from the recharge structure depending upon availability of water for recharge. These are the cheapest modes of artificial recharge but selection of a proper structure needs careful consideration. As already stated, artificial recharge for irrigation purposes is undesirable and as the requirement for domestic purposes varies accordng to population, it is better to select the structure according to requirement. For domestic wells of villages with population of less than 500, a normal village pond where not much elaborate arrangements for overflow are needed, is more than sufficient. However, it should be ensured that sufficient storm run-off is available for filling up the pond. If not, water from surrounding areas should be diverted to the pond with the help of minor trenches. Check dams are desirable only where the recharge requirement is very high. Out of the above 4 structures, that is, pond check dam, percolation tank and sub-surface dyke, the sub-surface dyke is the most suitable structure as it is safe from flood havocks, does not need elaborate overflow arrangements and periodic desilting. Even the problem of forest sub-mergence, which is becoming main hurdle in getting clearance for artificial recharge structures, does not arise in case of sub-surface dykes. The silt from the sub-surface near the sub-surface dyke is flushed away during flash floods whereas th entire storage of water being underground evaporation losses are also insignificant. the construction needs a 30 to 60 cm wide concrete or cement brick or cement masonary dyke extending down to impermeable basement or compact foundation. Two such sub-surface dykes of 100 m length each, within 300 m from the water supply well are enough to store water required for a village with population of 500. As the domestic wells are located close to the village, there is need for constructing these structures close to the village only. One of the structure should be upstream whereas other should be downstream. If only one structure is to be constructed, it should be downstream of the well. This is because the ground water mound created acts as a sub-surface barrier and reduces sub-surface outflow of ground water from around the well. During dry season, when the pumping water level in the well is low, the hydraulic gradient is reversed and the water is drawn from the ground water mound downstream.

The sites selected for construction of ponds, tanks, etc. during scarcity works are normally those where manual excavation is possible. Such sites are nothing but sites with intense weathering. As intensive weathering is manifestation of higher fracture porosity, the suitability of site is automatically justified. In alluvial area, hydrogeological investigations for site selection are not necessary on account of homogeneous nature of the formations.

iii) Basinwise Development for Artificial Recharge of Ground Water

In areas where rainfall is scanty and drought frequency is very high, conservation of every drop of rain water is essential. Out of the scheduled drought prone areas, worst affected areas can be selected for such schemes. The scheme for a particular basin comprises gully plugging in minor streams, sub-surface dykes or percolation tanks along tributaries streams, contour buding or trenching along hill slopes, farm ponds in the foot hill zones and wherever possible, check dam-cum-minor irrigation dams on the main stream. Land levelling (terracing) and afforestation along hill slopes also form part of basin development plan because they help in higher rainfall infiltration.

The most important factor in the design of artificial recharge structure is the consideration for its stability against probable higher storm run-off inflow during years of excess rainfall, occasional flash floods and safeguard against accumulation of silt and organic matters at the bottom. It was observed that the infiltration capacity of ponds reduces by almost 25%, each year, due to silting and by the end of 5th year it becomes almost 10% of the total storage. The 90% of stored water is thus lost on account of evaporation only. Providing side slopes of 1:1 for all recharge structures helps in maintaining constant infiltration through side :, because the steep slope does not allow accumulation of silt and also makes the sides quite stable. Dry stone ptiching is another safety measure against degradation of the structures.

For basinwise development, it is better to take up work in small basins where it would be easy to group the people in one society and to educate them. These schemes depend mainly on the co-operaiton of people as multiple activities like land development, wate harvesting, afforestation, etc. are involved. Moreover the achievements depend upon peoples participation and active contribution. The problem of shortage of funds if any can also be overcome, because close co-operation helps in people willing to come forward and take over management and offer "shramadan". As the normal areas of a village averages to 1000 to 1500 hectares, a basin with 1250 hectares area will be ideal.

iv) **Water Harvesting Structures :** Storage of rain waters in underground tanks or surface tanks is being practiced in the desert areas of western rajasthan and also in the high rainfall rareas of north-eastern region. The Technology Mission has designed rain water collection system for tiled roofs, thached roofs etc. In fact this system can be adopted in both rural and urban areas for houses with slanting or flat topped roofs. However, storage of the water in the tanks for use during the long period of dry season which normally extends for 7 to 8 months in major parts of the country, makes it necessary to take great care for keeping the water fresh and usable. Instead, structures should be designed for storing this water in underground rock formations and their utilisation by hand pumps or pumps. In hard rock areas, this water can be stored in small diameter (1 to 2m) shallow open wells (5 to 10 m deep) from where it will pass into the underground formations. With normal minimum intake capacity of 1 LPS for wells in hard rock, water can be stored @ 80 m^3/day (80,000 lit/day) whereas in alluvial area, well of same dimension can recharge water @ upto 200 m^3/day. With slow sub-surface movement of ground water, the water thus stored remains within the vicinity of recharge structure for a considerable period and is available for use during dry period. For wells in alluvial areas, concrete rings with weepholes for infiltration of water will have to be provided to prevent the well from caving. The water can be directly pumped from these wells also but installing hand pump on a shallow well a little distance away from this recharge shaft will provide naturally filtered water.

In urban areas the multi-storied housing societies can have one recharge-cum-pumping well each where fresh rain water from the roof tops can be diverted. During rainy reason, such medium deep tubewells can recharge the ground water aquifer to the extent of 80 to 240 thousand litres per day. If the water is properly filtered before diverting underground through tubewells, the water can be used for domestic purposes also - if not for drinkng, atleast for washing purposes. This will be the supply in addition to the normal supply by Municipal Corporation for drinking purposes.

In short, the suitablity of an artificial recharge structure can be tabulated as follows :

	Lithology	Topography	Type of structure feasible
I.	Alluvial or hard rock down to 40m depth	Plain area or gently undulating area	Spreading pond, sub-surface dyke, minor irrigation tank, check dam, percolation tank, or unlined canal system for diverting flood water for irrigation purposes
II.	Hard rock down to 40m depth	Valley slopes	Contour bunding or trenching. These areas are most suitable for afforestation-planting of trees along bunds or upstream of trenches. The forest cover reduces run-off rate. Where slopes are comparatively gentle, land levelling (terraining) also can be adopted

	1	2	3
III.	Hard rocks	Plateau regions	Recharge ponds
IV.	Alluvial or hard rock with confined aquifers below 40m depth	Plain area or gently undulating area	Injection wells or connector wells
V.	- do -	Flood plain deposits of rivers	- do -
VI.	Hard rock		Foot hill zonesFarm ponds or recharge trenches
VII.	Hard rocks or alluvium		Forested area Sub-surface dykes

6. PERIODIC MAINTENANCE

Periodic maintenance of artificial recharge structures is essential because the infiltration capacity reduces rapidly due to silting, chemical precipitation and accumulation of organic matter. In case of spreading structure, the annual maintenance comprises scrapping of the infiltration surfaces and removing the silt and organic matter whereas in case of injection wells and connector wells, periodic pumping and/or mild acid treatment for removal of incrustations and bacterial growths on slots is essential. By converting the injection or connector well into a dual purpose well that is pumping-cum-injection well, the interval of periodic cleaning can be prolonged but in case of spreading structures, except for sub-surface dykes, annual desilting is a must. As the artificial recharge schemes are carried out as relief works, no budgetory provision is kept for its periodic maintenance and it is observed that normally these structures are neglected in later phases. They only get the face lift during the subsequent drought relief work and fortunately, the droughts being frequent (5 to 7 year frequency), some maintenance does take place.

However, if it is decided to construct these structures only for augmenting the supply of domestic wells, the structures should form part of domestic water supply scheme and provision for its periodic maintenance be carried out by Public Health Engineering Departments or Gram Panchayats, whosoever maintains the well.

The basinal development where the recharge is mainly for irrigation purposes, being a multidisiciplinary scheme, the maintenance of minor irrigation tanks is normally carried out by the irrigation department, that of the contour bunding and trenching (along with afforestation) by the forest department and that of the farm pond and land levelling by the cultivators themselves.

7. CONCLUSIONS

i) For artificial recharge of ground water, rock formations with moderate permeabilities are most desirable. Low permeabilities reduce intake rate whereas high permeabilities do not allow retention of recharged water for a longer time to make use of it during dry season.

ii) Artificial recharge should be carried out only for agumenting domestic water supply as it is not economically viable for irrigation purposes.

iii) Artificial recharge for irrigation purposes should never be the main objective of any scheme. It should always be a by product, e.g.

   a) Minor irrigation tank which along with irrigation, increases ground water recharge by way of reservoir and canal seepages, recycled irrigation water and added rainfall infiltration due to levellinng of fields for irrigation purposes.

   b) Afforestation along hill slopes : The contour trenching and contour bunding which is normally carried out along with such plantations, helps in reducing the surface run-off.

   c) Basinal development schemes which comprise construction of farm ponds, afforestation, contour trenching and contour land levelling (terraining) and construction of check dams cum minor irrigation dams, where proper maintenance of structures is guaranteed due to involvement of Government agencies and cultivators.

iv) Injection wells or connector wells are costly schemes requring high order of quality control and as such are not desirable. However, where plenty of surplus groundwater is available in phreatic aquifers andthere is scope for accommodating this into the deeper aquifers, dual purpose that is pumping (for irrigation or domestic supply) cum recharge wells may be constructed.

v) Among spreading methods, sub-surface dykes are most desirable as they need very little maintenance, are safe from natural catastrophes evaporation losses are minimum and enviornmental problems arising out of water stagnation are avoided. There is no sub—mergence of land or forests also.

vi) If proper maintenance of existing recharge structures (ponds, trenches, percolation tanks) is carried out, there is no need for any further work in this direction as the present ground water development in the country is hardly 50% of the resources available. At the most, schemes like basinal development, farm ponds, etc. may be planned in advance and executed during drought relief works.

vii) Every domestic well should be supported by artificial recharge structure and its initial expenditure on construction and later expenditure on maintenance should be included in the domestic water supply scheme. This will take care of proper periodic maintenance of artificial recharge structure.

viii) For Urban Water Supply, where water is normally pumped from surface water reservoirs or from intake well (radial well or infiltration gallery) in the river bed, it would be advisable to construct the well in such a way that it would pump water from the ground water mound formed due to seepages and not from the storage in the river bed or reservoir. This will not only increase scope for induced recharge but constant diversion of water underground from surface storage, will help in saving losses due to evaporation.

ix) The drought relief works should be planned in advance (due to high drought frequency in the country these works are almost necessary, once in 5 to 7 years) and should include construction of new artificial recharge structures, renóvation of old ones and basinal development programmes.

x) Availability of rainfall water from the roof tops is so great, that if it is properly used for artificial recharge, it will not only reduce the pressure of demand on domestic water supplies but will also reduce the problem of disposal of storm run-off from city areas.

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CONSERVATION OF WATER RESOURCES*

Water is a prime natural reosurce, a basic human need and a precious National asset. It should be utilised in a Judicious manner. It has been estimated that out of the total precipitation of around 400 Million hecatare metres inthe Country, the surface water availability is about 178 Million hectare metres, out of this about 50% can be put to beneficial use because of topographical and other constraints. In addition there is a ground water potential of about 42 Million hectare metres. precipitation is confined to only about 3 to 4 months in the year and varies from 10 Cm. in the Western parts of Rajasthan to over 1000 Cm. at Cherapunji in Meghalaya. Further, water does not respect State boundaries. Not merely rivers but even underground aquifers often cut across State boundaries. Water as a resource is one and indivisible : rainfall, river waters, surface ponds, lakes and ground water are alls part of one system. Water is also a part of a larger ecological system.

Floods and drought affect vast areas of the Country. Floods affect an average area of around 9 Million hectares per year. According to the National Commission on floods, the area susceptible to flood is around 40 Million hectares. The approach to the management of drought and floods has to be coordinated an guided at the national level. The growth process and the expansion of economic activities inevitably lead to increasing demands for water for diverse purpsoes, domestic, industrial, agricultrual, hydropower, navigation, recreation etc.

The water resources available to the Country should be brought with in the category of utilizable resources to the maximum possible extent. The resources should be conserved and the availability augmented by measures for maximising retention and minimisng losses. Recycling and re-use of water should be an integral part of water resource development.

DRINKING WATER REQUIREMENT

As per 1981 census, there were 201 urban towns having a population of 72.00 lacs. If water supply to the towns having population more than 1.00 lac is considered @ 180 lpcd and 90 lpcd

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for remaining towns, than the total requirement of water in the State is about 1100 MLD for towns. For rural population considering supply @ 40 lpcd, the requirement would be about 1300 MLD. Compared to the increasing demand of water, the availability inspires deep doubts. To meet this demand and looking to the meagre water resources in the State, we should think for conservation of water resources and recycling of waste water.

CONTROLLING EVAPORATION LOSSES

In Rajasthan, we are using reservoirs water for irrigation as well as for drinking purposes. Cetyl Alcohol was found effective in reducing the evaporation losses. It was used in Ramgarh lake, Badi Dam and at other places too. The CMRI is presently trying to develop Poly molecular alcohols which may have a property of maintaining continuity of the film which will not get disturbed by high velocity winds. After these alcohols become available, it may be possible to save 25% to 30% of evaporation losses. In the event of drought, the surface sources get depleted and many a times are fragmented and become ineffective. At that time it becomes more pertinent to conserve the available quantity of water.

GROUND WATER

Ground water, though one of the earth's most widely distributed renewable resource, is not distributed uniformly all over the Country due to wide variation in Climatic conditions, physiographic features and hydrogeological environment. Precipitation is the main source of recharge, also take place through seepage from Canals, tanks and applied irrigation. A rough assessment of ground water resources has been made by the Central Ground Water Board. The annual utilisable ground water resources have been assessed as 18.30 KM^3. per year for Rajasthan State against a total of 422.86 KM^3 of the Country. The annual draft in Rajasthan is about 4.6 KM^3.

The first step in ground water resource development is to determine the location of suitable aquifer. This often involves re-connaissance survey of a given region using geological maps, sattelite imageries, ground observations and geophysical surveys to detect characteristic indicative of water bearing strata. The surface gephysical technique includes electrical resistivity survey and seismic refraction system. Remote sensing technique have been widely used in recent years for exploration of ground water. The aerial photographs and satellite imageries are very useful for studying the natural features such as soil cover, forest vegetation, agricultural lands, ground water potential zones etc. It helps to a great extent to identify the distinct valley fill areas which after being supplemented with available hydrogeological information may help in scientificially selecting the site for drilling of tubewells.

All efforts should be taken to conserve the available ground water resource for better use and augment the storage by increasing the natural recharge, salvaging a portion of water now being wasted and by developing artificial recharge methods. Many check dams, anicuts, ponds should be constructed for increasing the infiltration wherever feasible.

RAIN WATER HARVESTING STRUCTURES

Water is most precious commodity in the arid regions particularly due to prevalance of unfavourable hydrometeorological conditions. It would be less than honest if we remain dormant and only wait for good Monssoon. In Western Rajasthan, the quantity of water available from various sources as surface water and ground water are not sufficient even for drinking purposes. Over and above the insufficient quantity, the ground water is saline in a large area. Dissolved salts in ground water range from 1500 to 10000 mg/litre. Drought conditions also prevailing in these areas, therefore there is a need to collect rain water effectively at the appropriate time and utlise it judiclously so that the requirement of drinking water is met in a sustained manner for reasonable period. Therefore, in this area, the traditional techniques of rain water harvesting developed by the local people mainly Diggies, Tankas to be developed on the scientific basis.

Small scale harvesting structure can be completed in a short span of time and give immediate benefits. Innovative engineering interventions of this nature are desirable. The social benefits from such small scale interventions can be dispersed over a large population in short span of time.

In the case of high rainfall areas, in situ rain water harvesting is a plausible approach. In arid regions, techniques for embankment of runoff through catchment should be used. Sodium carbonate and Coaltar can be used for the treatment of Catchment area.

Polyethylene lining in diggies or storage tank remain effective for seepage loss. A diggi with filter unit is most scientific source of water supply in desert district like Ganganagar and Bikaner. Wasteful use of water by canals is nothing if not controversial.

RECYCLING OF WATER IN DROUGH PRONE AREAS

The complex system of monsson winds, orientation of mountains, deforestations, and erratic cyclones lead to exceesively low rain fall. The areas which gets a normal rainfall of less than 750 mm (30 inches) can be classified as drought prone. This is about 35% of the entire Country's area. Looking back on the droughts experienced in Rajasthan, during past years, it is evident that the number of drought years from 61-70 have increased from 3 in number to 6 from 81-88. Under such drought conditions, it has become essential to recycle the waste water after required treatment.

In view of above contents, it is desirable that the efficiency of utilisation of water in all the diverse uses should be improved and an awareness of water as a scarce resource should be fostered. Conservation consiousness should be promoted through education, regulation, incentive and disincentive.

WATER EVAPORATION CONTROL BY MONOMOLECULAR FILMS

INTRODUCTION

Large areas of India are arid or semi-arid. The problem caused by the loss of water stored in lakes and reservoirs for irrigation and domestic use by evaporation during the summer months is acute and perennial and this loss is enormous [see table 1]. Further more the supply of ever increasing qunatities of fresh water is a critical factor in our economy and the problem is becoming more pressing in view of our expanding population and agricultural and other industries. The reduction of evaporation loss of water is therefore nationally important.

A considerable amount of work has been carried out at the National Chemical Laboratory, Pune, both from fundamental and applied points of view. NCL has developed new type of compound called Alkoxy Ethanols having general formula $C_nH_{2n+1}OC_2H_2OH$ where n=16, 18, 20, 22. These compunds are more effective evaporation retardants than the corresponding Alcohols having general formula $C_nH_{2n+1}OH$. Recently we have observed from our preliminary experiments that mixed monolayers of Alkoxy Ethanols can withstand high wind velocities in the laboratory wind tunnel experiments. We will report highlights of our results obtained in this area from this laboratory.

EXPERIMENTAL

π - A isotherms of various Alcohols and Alkoxy Ethanols were obtained using Langmuir horizontal film pressure balance[1-2]. Wind tunnel[3] which was constructed in the laboratory was used for measuring wind velocities. Films are exposed to 39 km/h for two hour duration along with blank. Percent evaporation reduction were calculated knowing the evaporation in the blank and in the film covered water surface.

RESULTS AND DISCUSSION

Typical results obtained from these compounds are given in tables 2 and 3. It is clear from the tables that the rate of spreading equilibrium, spreading pressure and collapse pressures are higher in the case of alkoxy ethanols as compared to corresponding Alcohols. Results obtained

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from wind tunnel experiments are tabulated in the Table 4. It may be observed that Alkoxy Ethanol mixtures especially $C_{18}OC_2H_4OH + C_{22}OC_2H_4OH$ (1:9) gave very high results at 39 km/h as compared to $C_{16}OH + C_{18}OH$ (1:1) used commonly. We are trying to confirm the results by repeating them number of times. Once this data is confirmed we shall be able to go ahead with the preparation of these Alkoxy Ethanols on large scale for utilization in the lakes and reservoirs.

Table 1

***Estiamted water surface area in India for water evaporation control by monolayer films**

Area of arid, semi-arid and long dry spell regions of India	2,000,000 sq.km.
Estimated water area in these regions (1%)	20,000 sq.km.
Estimated area where film application may be feasible	2,000 sq.km.
Evaporation losses of water over these per year [Estimated depth of 3m]	6×10^9 m^3 $= 1.32 \times 10^{12}$ gallons

(* L.A. Ramdas, proc. sumposium on water evaporation control P-14, 1966)

Table 2

Rate of spreading and equilibrium spreading pressure of n-long chain Alcohols and Alkoxy Ethanols at 25°C

Compound chain length	n - Alcohols			n - Alkoxy ethanols		
	M.P.°C	π e dynes/cm	dN/dT	M.P.°C	π e dynes/cm	dN/dT
C_{16}	49.5	39.6	2.8×10^{13}	43.5	50.4	2.3×10^{15}
C_{18}	59.4	35.2	1.1×10^{12}	51.7	48.9	1.8×10^{14}
C_{20}	64.5	32.6	7.6×10^{11}	60.5	49.0	1.2×10^{13}
C_{22}	71.0	27.6	6.0×10^{11}	65.6	47.2	1.5×10^{12}

Table 3

Collapse pressure π_c and area per molecule from π A isotherm

Compund	Collapse Pressure c (dynes/cm)	Area/molecule A° A^{o2}/molecule
$C_{16}OH$	43.0	19.3
$C_{18}OH$	39.0	19.4
$C_{22}OH$	37.0	19.2
C_{18}-OC_2H_4OH	42.0	18.6
C_{22}-OC_2H_4OH	45.0	19.2
C_{16}-OH + $C_{18}OH$ (1 : 1)	47.0	18.9
C_{18}-OH_2H_4OH + C_{22}-OC_2H_4OH (1: 1)	47.0	19.3
C_{18}-OC_2H_4OH + C_{22}-OC_2H_4OH (1 : 9)	49.0	19.5

Table 4

Wind Tunnel Experiments on Water Evaporation Control

1. Wind velocity : 39 ± 1 km/hr
2. Compound Added : 5 x monolayer

Experiments in the Month of March, April, May 1988

Compund	Room Temp. Average	% Humidity Average	% Reduction
C_{16}-OH	32.3	50.3	18.0
C_{16}-OH + C_{18}-OH (1: 1)	35.5	43.4	34.6
C_{18}-OC_2H_4OH (Pure)	34.8	48.5	54.9
$C_{22}OC_2H_4OH$ (Pure)	35.9	51.3	63.7
$C_{18}OC_2H_4OH$ + $C_{22}OC_2H_4OH$ (1 : 2)	35.4	48.0	65.6
$C_{18}OC_2H_4OH$ + $C_{22}OC_2H_4OH$ (1 : [illegible])	35.6	49.3	61.3

Experiments in the Month of June, July 1988

$C_{16}OH$	34.8	53.8	17.8
$C_{16}OH + C_{18}OH$ (1 : 1)	28.8	68.0	51.5
$C_{16}OH + C_{18}OH$ (1 : 3)	28.9	65.0	63.2
$C_{18}OC_2H_4OH$ (Pure)	32.0	52.5	67.3
$C_{18}OC_2H_4OH + C_{22}OC_2H_4OH$ (1 : 9)	34.0	51.4	74.6
$C_{18}OC_2H_4OH + C_{22}OC_2H_4OH$ (1 : 1)	29.9	64.7	71.3

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KOLHAPUR TYPE WEIRS - A BRIEF RESUME*

SYNOPSIS

Kolhapur type weirs are in use for more than fifty years in Kolhapur District of Maharashtra. They are open type weirs across streams. These structures are basically irrigation structures, best suited for harvesting medium type streams through small size projects. These structures can be constructed and maintained using traditional and local skills. Adoption of modern technology is however a matter to come in immediate future. The areas of application are identified as hilly and geographically unsuitable area for conventional flow irrigation, irrigated area spread in small patches, streams with heavy silt loads.

KOLHAPUR TYPE WEIRS

Kolhapur District in Western Maharashtra is well known for its rich agriculture. It is probably the only example where the full irrigation potential has been harnessed, through lift irrigation. Most of the area of this district is hilly being close to or part of Western Ghats. A number of rivers traverse through this area & they belong to the Krishna basin. Geologically this is part of the Deccan plateau.

Though this is mainly on assured rainfall zone, presence of basalt flows has laid down limitation on the scope of well irrigation. So also the geography does not permit development of conventional flow irrigation systems on large scale. Since the rivers are mansoon fed, development of irrigation essentially depends upon building up of storages. It will be intersting to know that in spite of assured & rich precipitation, only two major storages have been constructed in this districts. The irrigation development, relatively, is however very large and infact a success story.

Kolhapur type weirs has been the key to the success.

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THE WEIR

A Kolhapur type weir, unlike other weirs, is an open bandhara, it is like a miniature barrage. The structure is actually a series of solid masonry pillars supported on solid unyielding foundation across a river. The pillars are equidistant and a slab runs on the top. This open weir offers very little obstruction to the flow when the river is in full spate. Thus high floods in mansoon pass through, almost as if there is no structure. The 'open' portion i.e. the gaps between successive pillars plugged in October/November every year using wooden needles. the needles fit in the grooves specially provided for on the sides of pillars. There are two parallel rows of grooves on pillar sides and at the sill level. This arrangement enables erection of two partitions spanning the pillars across the flow. The space between two partitions is filled using clayey soil, thus making the partition watertight. The Kolhapur type weir now acts like a conventional bandhara, with a counterfort like section. The water impounded and the run-off the river are used for lift irrigation.

The wooden needle are removed in every May. The bandhara is then ready to pass the mansoon flow. The bandhara now behaves like a submersible bridge. The foundation structure for such bandharas is of solid rubble stone masonry and rests on hard rock essentially. The top of this foundation i.e. the sill is paved. The sill level is not constant throughout the length but varies to match the river cross section in view of minimum obstruction to flow. The pillar height varies accordingly. The top slab is R.C.C. & is anchored to the pillars. It acts as a roadway slab, access for maintenance & contributes to the structural strength of pillars. Advantages of Kolhapur type weirs over conventional weirs;

(i) This type of construction almost eliminates accumulation of silt on up stream side. The flood water that carries maximum silt passes through in the mansoon. So also the flushing action of the flood water is very effective.

(ii) Large & medium size streams can be harvested by investing much smallar sums. Isolated areas can be served effectively. No submergence or land acquisition is involved.

(iii) The areas which are not suitable for conventional flow irrigation can be best served.

(iv) The concept of phase development of project is materialised. The K.T. Weirs are constructed first. Put in use and are later supported by back up storages. The river functions as the main distribution channel.

CHOICE OF SITE

The site that offer a sound foundation grade rock at shollow depth, minimum width and having streadily rising strong banks are best suited. Weir across rivers with flatter slope have a relatively lower per unit cost of storage. In Kolhapur district, wherever there are back up storages, the sites are so chosen that backwater of a weir at F.S.L. reaches the other weir immediately on upstream. This is more relevant for weirs with backup storages. In this case, water from the main storage is released for each rotation & storage in weirs is recouped from downstream to upstream. the operations are controlled by using the needles as stoplogs.

OPERATION & MAINTENANCE

The needles used are hard jungle wood needles (Kinjal, Jamun, Mango etc.) The minimum thickness of needle upto 3 M. of hydraulic head is 75 mm. For higher heads 150 mm thick needles are used. All these operations are manual & hence the weight of needles is restricted to around 50 Kg. each or so.

The lowering of needle strats around October end. The schedule is so chalked-out that occurance of later high floods is avoided and at the same time filling of weir is achieved. The schedule is more sensitive for weirs on smaller river and those located in remote areas. The panels are plugged one by one. As the water level rises, plugging becomes more difficult lot of soil is washed away at later stage. The maintenance procedure is however standerdised with passage of time. About 10% of needles are required to be replaced annually.

The prohibitive cost of J.W. needles has forced search for alternatives. Curved steel plates are used in place of J.W. needles. The plates are reinforced for strength & convenience of operations. As a policy matter, steel plates are replacing the jungle wood neeles. In case of use of steel plates, single wall partition is enough. No soil is required in this case.

ADDITIONAL ADVANTAGE

Use of the weir as submersible bridges have become a common practice. The approach roads however are never in cutting as it invites outflanking.

NEW TRENDS

Structural concrete is being used for cut waters and in place of paving. Rolled sections are replacing out stone grooves being more accurate and convenient.

At present about 85 K.T. Weirs in Kolhapur district are in use, some of them are backed by storages. Some of these weirs date back to thirtees when they were introduced by the earstwhile ruler, the great Shahu Chhatrapati of Kolhapur State.

At present in Kolhapur district, six medium projects are under construction. All these envisage the confirmation of K.T. Weirs & L.I. Schemes as the distribution system. All the L.I. Schemes are either in private sector or in co-operative sector.

INTEGRATION OF WATER HARVESTING STRUCTURES INTO THE DRINKING WATER PROGRAMME

IRRIGATION OF WATER HARVESTING STRUCTURES INTO THE DRINKING WATER PROGRAMME — EVOLVING GUIDELINES

Introduction

Rain water harvesting structures have been in use for centuries by our people. People have been using these structures for irrigation as well as drinking water purposes. Even during severe scarcity/drought conditions people have been managing with these structures and meeting their demand and water. People know about construction, operation and maintenance of these structures. All these suggest that we may have to look into the traditional water harvesting structures in depth and suggest measures how best we can integrate these with the drinking water supply programme in a systematic manner.

The water supply departments (PHED in most cases) have conventionally been primarily agencies providing drinking water by exploiting ground water resources. But today we are at such a point of time when realisation has dawned on everyone that the resources we are exploiting are not infinite. Water is in fact a scarce resource in most areas and any "user" desirous of steady supply will have to be conscious of the need to regulate and augment his resources. There has to be therefore a shift in emphasis to "management of water resource" as different from "exploitation of a resource" for the PHED Engineer. It is here that water harvesting structures offer him an opportunity. He can avoid depletion of the water resource and effect augmentation by bringing management of water harvesting structures within his fold. In the process it will also offer him an opportunity to gain fresh insights into the management of water by society and add to his knowledge-base an entire new area of "people's technologies" unfortunately overlooked until now.

Water harvesting structures serve mainly three functions for the PHED Engineers or water supply departments :

(a) They recharge aquifers and thereby augment the source and effect better overall ecomanagement.

(b) In some cases they directly supply or supplement drinking water to the people.

(c) They serve to take away some demand on water supply made by livestock and demands other than drinking like washing, bathing, etc. since surface storages serve this purpose.

It is, therefore, absolutely essential to integrate water harvesting structures into the agenda for action by water supply departments. But here it is necessary to discuss the kinds of water harvesting structures that can get directly integrated with a programme of action by water supply departments. While all water harvesting structures cater to two purposes detailed above that of recharge of aquifers and catering to demand of livestock and uses other than drinking, there is a category of water harvesting structures which directly can be used to provide, or supplement drinking water needs. They are those like NADIS, TANKAS, SAND FILL RESERVOIRS, PONDS, ROOF TOP COLLECTIONS, HILL TOP COLLECTIONS, OORANIS, ETC.

The point to consider now is how best we can effect an integration of these structures into the water supply department's mainstream activity or what is a methodology for such integration. This is an issue on which this forum is called upon to throw up a few answers. We are detailing below a few methods which could serve as a basis for this discussion :

(a) The first and foremost issue is that if we concede that water harvesting structures can be relied upon to provide drinking water, then that has to get integrated into the drinking water supply activities under ARWSP/MNP for funding. This alone will prompt the engineers to even start looking for lower cost options offered by the traditional structures.

(b) There has to be decision making in favour of water harvesting structures at the State level. One problem today is that at the State level there is no policy making forum which looks into water management issues in toto and allocates the resource based on principles of sound management between competing demands of agriculture, industry, drinking water, etc. It is essential to create such a forum at the State level with the Chief Minister as its Chairman and representatives from departments of PHE, industry, agriculture, forests, rural development, NGO's and people's representatives. The mandate for this body would be to effect just and sound water management. Today, if the PHE's are faced with a problem of a depleting water table in an area and there is a need to have a large network of water harvesting structures in that area, this forum will have the powers to assign the rural development or the department or the agriculture with the task to take up such works. The technical and administrative and financial resources of all departments become available in a pooled manner to take up such measures.

This State level body should be provided technical support by GOI by pooling the S&T resources of CGWB, NGRI, etc. This has successfully been done by the National Drinking Water Mission for locating sources in problem villages. Similar support for water harvesting structures will be very useful. This State level body with representation from all areas concerned will help PHEs to tackle their difficult areas through an integrated approach.

(c) A similar forum for integration should be worked out at the district level with the collector as coordinator. The district development plans could then be so modified to upgrade and rejuvenate these traditional structures. The district level water management committee with representation from departments of agriculture, forest, irrigation, geohydrology PHE and the DRDA will be able to work out a plan for management of water harvesting structures in the district.

(d) A district level inventory of water harvesting structures should be prepared by the district level body and later a State level document should be got prepared. Based on this, specific instructions for periodic repair could be specified. Funding under NREP and RLEGP could become available for this purpose.

(e) Individual structures for roof top collections should receive funding under NREP/ RLEGP. An analogy for this could be the assistance made available under RLEGP - Indira Avas Yojana - for housing. Water supply being a basic need should become eligible for such assistance. This would result in PHED's being able to take up work in private holdings.

(f) Training should be given to PH engineers in geohydrology, water management and in environment management to enable them to look at the problem of drinking water holistically. There is an urgent need to institutionalise such training at State level and Central level.

(g) There may also be areas where rain water harvesting structures can be cost effective for tackling the quality problem - e.g. the saline areas in the coast. They should therefore be taken up in such areas by state governments.

(h) Similarly in hill areas rain water harvesting structures offer a low cost solution. PHED's of hill States should therefore make it the first option to be evaluated in areas where they are feasible.

(i) The geographic areas where they are recommended should be detailed by the States.

To summarise, water harvesting structures be made an integral part of the drinking water programme, to be handled by the PHED's. In doing so, the following aspects are to be considered :

(i) In most areas WHS can only augment/supplement and not replace the conventional sources.

(ii) If so, what would be the percentage or requirement of water that has to be augmented and this has to be worked out judiciously.

(iii) Inventory of structures that can be used for meeting drinking water need to be prepared.

(iv) Norms for improvement and maintenance of these structures have to be worked out.

(v) It has to be clarified whether the ownership would rest with the individual, community, gram panchayat or the department.

(vi) Naturally the Nodal agency would be the PHED for upgradation of these structures and bringing them into PHED fold for maintenance at par with all water supply systems.

(vii) Once these structures form part of PHED, it is for the PHED to monitor the quality of water and ensure safe suply.

(viii) The work carried out in RLEGP/NREP/DPAP/DDP have to get linked with PHED through themechanism of the district level committee.

(ix) Technology inputs for upgradation of these structures should be worked out including location through geophysical surveys, use of ferrocement, evaporation retarders, agrofilm and other lining material etc.

While deliberating on these issues, the forum may also suggest measures to retain and where not existing restore a comunity based management of these systems with government only aiding their improvement and management.

GROUNDWATER RECHARGE THROUGH PERCOLATION TANKS AND SUBSURFACE DYKES*

ABSTRACT

Hard rocks occupy over 80% of the Southern Peninsula. Due to wide variation in rainfall, geomorphology, geology and hydrogeological conditions, the distirbution of groundwater varies from place to place as vast area comes under semi arid tract with low rainfall. Groundwater is developed generally through open wells. Due to the accelerated development of groundwater, water levels have declined considerably. Investigations were carried out to study the effect of percolation tanks as a structure for recharging the ground water reservoirs and the effect of subsurface dams to arrest the ground water movement and to utilise the storage thus created at the time of need. The paper presents the results of these investigations.

INTRODUCTION

The Southern Peninsula comprising the states of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu has an area of 6,38,000 sq.km. of which 5,41,895 sq.km is occupied by hard rocks consisting of igneous and metamorphic rocks and consolidated sedimentary rocks. It recieves rainfall both from south-west and north-east monsoons. The Western Ghats which lies in the path of south-west monsoon currents has a great bearing on the rainfall distribution. The Western Ghats and the region west of its are humid with heavy rainfall whereas the area east of it has a low rainfall ranging from 450 - 1000 mm. The rain shadow effect of the Western Ghats extends inland to a distance of more than 200 km wherein lies the areas having annual rainfall less than 600 mm. This area is mostly underlain by the hard rocks and ground water is being developed through open dug wells. With increase in demand of water due to increase in population and agricultural needs the water levels have gone down considerably and in certain parts well have gone dry. The open wells are generally 5 to 10 m in diameter and than 30 metres and every year farmer deepens the wells due to decline in holes have been put down to meet the Rural Water Supply Schemes and inwell bores for agricultural purposes.

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Ground water is a dynamic renewable natural resource which is always on the move. This resource is replenished annually by the precipitation and also by the recycled water especially in the command areas of major irrigation projects. It is generally well known that the occurrence of gorund water and its availability for the various uses is controlled by the nature of the rock formations in which it occurs, the geological structures, geomorphological and hydrogeological setting and hydrometeorological conditions. It is common knowledge that water levels in wells go down during summer or drought periods and come up after rainy season or wet spells. This is the natural response of the ground water reservoir to recharge through precipitation, seepage, return flow from irrigation and discharge through pumping, evapotranspiration and baseflow. Since the ground water is dynamic in nature, its movement is generally controlled by gravity and flows in the down gradient direction from a higher elevation to lower elevation through the porous and fractured rock media. The resource which is not beneficially utilised either due to availability of other sources like surface water or rainfall, the ground water is lost as subsurface runoff to the sea.

Ground water which is abundant and plenty in the major river valleys of the north is not that much abundant in the south except in the deltaic area due to the nature of the terrain, the topography and the geological setting and the prevailing hydrometeorological conditons. More often because of the varied climatic conditions recurrence of drought is a common feature in the south. Added to this, Man's activities in disturbing the natural eco-system has also contributed to the lowering of water tables in these areas. Since most of the surface water sources have been harnessed, the picture gets much more complicated. So in a situation like this, it is but natural to search for a suitable methodology for better management of the ground water resource available in the southern part of the country which is mostly underlain by the hard rocks. Such methods include artificial recharge, better water use and conservation technique and change of cropping pattern. thepaper deals with studies carried out by the Central Ground Water Board on percolation tanks and subsurface dykes.

I. PERCOLATION TANKS

percolation tanks are generally constructed on the small streams or revulets with adequate catchments. these tanks will have only surplus weirs as these are used entirely for recharging the aqquifers. there are a number of percolation tanks in the Noyil, Vattamalai Karai and Ponnani River Basins where attempts have been made to conserve the storm runoff and induce percolation to ground water for better resources management due to prevalence of low rainfall tract.

The percolation study has been taken up with the following two important objectives :

(a) To have an idea of fillings of the tanks due to monsoon in connection with the tank storage and

(b) To study the trend, rate and quantum of percolation

The storage of percolation is monitored continously or periodically depending upon the importance. Along with the stage, pertinent particulars regarding the flow through different arrangements has been noted along with the duration of occurrence.

Area of water spread capacity

The tank is surveyed and a contour map prepared. From contour map, the area of water spread and capacity of various stages from minimum possible stage to full tank level are determined by planimetering the inter contour area and considering the contour interval.

Tank stage

The stage hydrographs of the tank are drawn and from this, number of fillings was obtained which can be quantified from the tank capacity details.

Percolation

From the stage hydrographs certain periods are selected in which there is no outflow except by evaporation and percolation. Knowing the change in capacity over the duration of the period under consideration and the evaporation from the tank, quantum and rate of percolations are determined. Also the rate of percolation in different strategic periods give the idea on trend of percolation.

For carrying out the studies and to assess the effectiveness in checking storm runoff and aiding deep percolation the following tanks in various parts of Coimbatore district of Tamil Nadu were selected covering different soil types.

(a) Noyil Basin

1. Chinnathadagam
2. Annur
3. Kanur
4. Asanallipalayam
5. Karavellur
6. Avanashi

(b) Vattamalai Karai Basin

1. Pilliampalayam
2. Vattamalai

(c) Ponnani Basin

1. Kodavadi

Stream gauge stations were installed at all these tanks to record the runoff and changes in storage. For computing the change in storage the area of the water spread and capacity V/s stage height were prepared for all these tanks and the daily change in storage were read directly from the storage calculated from the stage height.

The salient features of tanks are given in Table 1 and particulars related to annual storage, evaporation and percolation given in Table 2. The gauge data and the corresponding capacity and area of water spread are given for three tanks in Fig. 1 to 3.

Analysis and interpretation of data

The daily changes in storage were comptued due to evaporation, runoff and percolation to ground water. The evaporation losses were computed from the available potential evaporation data of the nearest weather station. From this, the net evaporation and percolation losses in mm/day respectively were computed for each tank. From this the daily changes in storage, the annual changes in storage, percolation and evaporation were computed and are given in the Table 2.

The salient features observed from the data obtained are that the rate of percolation was high immediately after the inflow into the tank. This rate was as high as 163 mm/day at Karavallur tank but generally varies from 50 mm to 150 mm/day. The rate of percolation seems to be 10 to 20 mm/day during the non-monsoon period or after a long period from the date of inflow into the tank.

The studies indicate that the tanks at Kanur, Annur, Kodavadi and Vattamali contained water for longer period of time and the rate of percolation in these tanks was considerably low when compared to the other non-perennial tanks. This perhaps may be due to the long standing water column which may facilitate the suspended silt to accumulate on the bed and act as an impervious layer. In case of non-perennial tanks, the tank bed is desilted every year by the Farmers as they spread this silt on other fields to increase the fertility. This process has increased the percolation rates in the non-perennial tanks.

From the table it could be seen that the annual evaporation and percolation losses are around 15% and 85% respectively of the total storage of the tanks. In case of Annur and Kanur, the evaporation losses are more due to the availability of water in the tank for a longer period of the year.

Influence of percolation tanks on the wells

Studies were also carried out to study the influence of percolation tanks on the nearby wells by establishing observation wells both on the upstream and downstream side of the ponds and monitoring the water levels regularly. Thirteen percolation tanks were selected for such studies in parts of Coimbatore district of Tamil Nadu and observation wells were established both on the upstream and downstream side of the ponds and water levels monitored weekly. Hydrographs of wells located on upstream and downstream sides of three percolation tanks are given in Fig. 4 to 6. Table 2 presents the data of the studies carried out in this connection. It is evident and clear from the results of the above studies that percolation tanks are very effective in conserving the storm runoff and inducing percolation to ground water. Studies indicated that these are beneficial to small farmers and they can arrest the declining trend of water levels in the vicinity. Thus there is a need to have more and more number of percolation tanks especially in drought prone and semi arid areas to conserve whatever rainfall comes during the pre-monsoon and monsoon seasons and store them "underground". However, a word of caution has to be added here. The comparative studies carried out by the Central Ground Water Board under the same project in Tamil Nadu has shown that percolation rates were low in black cotton soil areas than from the tanks located in the red soil areas as evaporational losses are minimum. Hence it is suggested that before any large scale construction of percolation tanks are taken up the soil types may be mapped in detail and their infiltration characteristics are studied so that suitable sites are selected to derive maximum benefits.

II. SUBSURFACE DAM

It is a subsurface structure built to arrest the subsurface flow of water from a catchment or a watershed. Such structures are feasible in narrow gently sloping valleys where the bedrock occurs at shallow depth and valley fill consists of 4 to 8 m thick pervious material. The catchment should have good rainfall to recharge the subsurface dam and also to wash out the excess salt to be accumulated in the top soil due to recycling.

The subsurface dam/dyke consists of an impervious wall with a jack well and a collector well which are interconnected and this can be on the upstream of the dyke or along the dyke section itself. These dam/dykes can be constructed with material like tarfelt, resin, polythene sheets, bitumen, clay besides bricks and concrete, depending on the local conditions and the economic benefit to be accrued. The wall of the dyke to be built will be very thin and there is no need for any buttresses, as the passive earth pressure of the soil will take up the water pressure. Besides the structure is finished at a depth of about one metre below land surface.

(a) Case Study

One of the objectives is to carry out experiment to increase the subsurface storage of ground water by constructing a subsurface dam with a view to its optimum utilisation and management which will raise and improve the economic and social conditions of the people of the area through increased agricultural production. The dam also has to be built by using various cheaper materials like clay, bitumen, tarfelt, polythene sheets besides brick to study their impervious nature and to reduce the cost of the dam.

With the above objective in view the surveys were undertaken at Government Seed Farms at Eruthampathy, Anangadi and Kongad in Palghat district. These Farms were selected as they belong to the State Government and there will be no difficulty in carrying out the experiment and also will help in continuing the observation through the state agency even after the completion.

The detailed investigation was taken up at the site located at Ananganadi Seed Farm which lies at a distance of 4 km on the road to Kothakurussi from the bifurcation of Ottapalem-Shoranur road. It is situated in a valley, sloping from west to east and has an area of 7.13 hectares with an average annual rainfall of about 2300 mm. The Area is underline by granites and gneisses which are exposed in the area. The outcrops occur on both sides of the proposed dyke.

A site plan was prepared with 5 m contour intervals. the depth to bed rock was sounded at 19 places along six lines with hammer sounding which indicated that the depth to bed rock varied from 5.3 to 7.7 m Electrical Resistivity sounding at an interval of 15 m distance was carried out along the proposed alignment of the dyke besides hammer sounding to corroborate the depth of the bed rock.

Five piezometers for monitoring water levels and three access tubes for monitoring the soil moisture through Neutron Probe were established.

Soil samples collected were analysed for their physical properties and aquifer properties. The specific yield determination was made through tension plate in the laboratory and in the field through the Neutron Probe.

The studies indicated that the section between 40 and 60 metres and 120 and 140 metres on the dyke line is more clayey and the section between 61.5 and 99 metres is more sandy. The thickness of the weathered mantle is about 0.5 m.

The specific yield studies through tension plate indicated that the top layer is more clayey and between 0.9 and 4 m. bgl is sandy for most of the part in the zone of water level fluctuation. The average specific yield value obtained through tension plate is 9.7% whereas the Neutron Probe method has given an average specific yield value of 4 to 4.2%. Therefore for caculation of ground water storage an average specific yield of 7.5% has been taken in the vicinity in the top zone.

(b) Design and Construction

Based on the results of the investigation it was decided to construct a dyke of 150 m in length trending in N 10° W to S 10° E with its height varying between 3 and 4 metres. Brick was used to construct the dyke wall in the central portion of the valley while tarfelt was used at flanks. Polythene sheet was used for a width of 4 metres between the brick wall and the tarfelt as good polythene sheet was not readily available. Similarly clay could not be used as it was not available nearby and bringing it from a long distance would have increased the cost. Of the 150 m length first 65 m is of tarfelt on the flanks, 81 m of 10 cm brick in the central portion and 4 metres of polythene sheet (Fig. 7). A jack well of 4 m diameter and 8.2 m was constructed at 0/035 m and semi-circular collector well of 5.5 m deep was constructed at 24 m north of the jack well. These two wells are connected by the two 50 mm diameter holes drilled through the massive rock occurring between them. Similarly the deep weathered zone encountered at 30 m north of the collector well is also connected through 50 mm diameter horizontal bore. Horizontal bores were drilled in the collector well in different directions upto a length of 30 m to tap various fractures occurring in the upstream area to increase the effective radius of the well and for easy flow of water into the well.

After the construction of the dyke wall with various materials mentioned above piezometers were planned on both sides of the dam at 20 m distance to monitor the water levels to study the effectiveness of the materials used. The piezometers are 37 mm diameter G.I pipe with slotted section at the bottom which has been srounded with gravel. The downstream portion was filled with the excavated soil and on the upstream side, the bottom most portion was filled with pebbles and jelly and it is covered with a layer of sand to facilitate easy percolation and for the accumulated water to flow easily towards collector and jack wells. In the jack well 150 cm diameter pipe column with slotted section at the bottom has been lowered to monitor the water level during pumping and recovery periods with help of automatic water level recorder. The water level data in the pizometers have indicated that the levels in the piezometers on the upstream and downstream of the same section shows difference indicating that the materials used for the construction of dyke are impervious.

The cost of benefit ratio of the structure worked out to 1.06 taking into account additional crop that can be grown in the area.

The advantage of the subsurface dam are :-

(a) It is cheaper to construct, as the thickness of the wall is very thin compared to normal dams where water pressures has to be taken up by a thick wall with buttresses. As the water pressure in the subsurface dam is taken up by the passive earth pressure of the soil downstream, the material used for the wall can be any impervious material like, plastic membrance, tarfelt or clay.

(b) The evaporation is very low.

(c) The reservoir area can be used for cultivation and no land is wasted for tank.

(d) The riparian rights of the downstream farmers are not affected as the dam does not project out and lies beneath a depth of 1 m below the land surface of the lowest elevation of the catchment area.

(e) Recycling of the impounding is possible as infiltrated applied irrigation water flows towards the dam.

Table 1

Salient features of the gauged tanks in Noyil, Amaravathy and Ponnani Basins

Sl. No.	Name of Tank	Name of Basin	Catchment area in Km²	Minimum bed level in m.	Full tank level in m.	Full tank depth in m.	Full tank capacity in MCM	Full tank water spread area in million m²	Percolation % rate	Evaporation rate %
1.	Chinnathadagam	Noyil	–	95.85	98.55	2.70	0.0354	0.0344	89.85	10.15
2.	Annur	–do–	12	95.15	100.90	5.75	2.5792	1.5558	66.63	33.37
3.	Kanur	–do–	13	93.83	100.00	6.17	1.4058	0.5909	–	–
4.	Asanallipalayam	–do–	6	92.68	98.898	6.218	0.3800	0.1800	92.29	7.71
5.	Karavallur	–do–	5	94.465	100.00	5.335	0.6428	0.2785	81.82	18.18
6.	Avanashi	–do–	140	97.23	98.415	1.185	0.0029	0.0055	94.02	5.98
7.	Vattamalai	Amaravathy	300	97.06	99.82	2.760	0.0671	0.1610	85.49	14.51
8.	Pilliampalayam	–do–	9	96.95	99.100	2.15	0.0087	0.0199	83.00	17.00
9.	Kothavadi	Ponnani	112	91.025	98.440	7.415	1.224	0.5280	88.00	12.00

Table 2

Detals of storage, percolation and evaporation in different tanks in Noyil, Amaravathy and Ponnani Basins

Sl No	Name of Tank	Name of Basin	Annual Percolation in MCM			Annual evaporation in MCM			Annual storage in MCM			Av Annual rate of percolation in mm/day.
			1976	1977	1978	1976	1977	1978	1976	1977	1978	
1	Chinnathadagam	Noyil	0.006	0.006	0.004	0.0009	0.0009	0.0006	0.0080	0.0066	0.0045	20.00
2.	Annur	–do–	0 167	0.450	0.240	0.084	0.225	0.120	0.251	0.675	0.360	10.00
3.	Asanallipalayam	–do–	0.205	0.239	0 049	0.017	0.02	0.041	0.222	0.259	0.09	30.00
4.	Karavallur	–do–	0.543	0.662	0.452	0 119	0.146	0 101	0.662	0.809	0.56	30.00
5.	Avinashi	–do–	0.010	0.005	0.006	0.0006	0.0003	0.0004	0.0106	0.0056	0.0064	50.00
6.	Vattamalai	Amaravathy	0.322	0.668	1.523	0.055	0.113	0.249	0.377	0.781	1.772	42.00
7.	Pilliampalayam	–do–	0 023	0.051	0.051	0 0045	0.01	0.01	0.028	0.061	0.061	30.00
8	Kothavadi	Ponnani	0.0937	1.914	1.359	0.098	0.201	0.143	1.035	2.115	1.502	26.60